PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Commissioner
US Department of Commerce
United States Patent and Trademark Office, PCT
2011 South Clark Place Room CP2/5C24
Arlington, VA 22202
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 12 December 2000 (12.12.00)	
International application No. PCT/EP00/03171	**Applicant's or agent's file reference** M/41157
International filing date (day/month/year) 10 April 2000 (10.04.00)	**Priority date** (day/month/year) 21 April 1999 (21.04.99)
Applicant BRAMBILLA, Massimo et al	

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International Preliminary Examining Authority on:

20 November 2000 (20.11.00)

[ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was

[ ] was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No.: (41-22) 740.14.35

Authorized officer

Olivia TEFY

Telephone No.: (41-22) 338.83.38

NK

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF THE RECORDING OF A CHANGE

(PCT Rule 92bis.1 and Administrative Instructions, Section 422)

To:

KINZEBACH, Werner
Reitstötter, Kinzebach & Partner
Sternwartstrasse 4
D-81679 München
ALLEMAGNE

Date of mailing (day/month/year)
28 November 2000 (28.11.00)

Applicant's or agent's file reference
M/41157

IMPORTANT NOTIFICATION

International application No.
PCT/EP00/03171

International filing date (day/month/year)
10 April 2000 (10.04.00)

1. The following indications appeared on record concerning:

[X] the applicant [ ] the inventor [ ] the agent [ ] the common representative

Name and Address
DE NORA FUEL CELLS S.P.A.
Via Bistolfi, 35
I-20134 Milan
Italy

State of Nationality: IT
State of Residence: IT
Telephone No.:
Facsimile No.:
Teleprinter No.:

2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:

[ ] the person [X] the name [ ] the address [ ] the nationality [ ] the residence

Name and Address
NUVERA FUEL CELLS EUROPE S.r.l.
Via Bistolfi, 35
I-20134 Milan
Italy

State of Nationality:
State of Residence:
Telephone No.:
Facsimile No.:
Teleprinter No.:

3. Further observations, if necessary:

4. A copy of this notification has been sent to:

[X] the receiving Office
[ ] the International Searching Authority
[ ] the International Preliminary Examining Authority
[X] the designated Offices concerned
[ ] the elected Offices concerned
[ ] other:

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No.: (41-22) 740.14.35

Authorized officer
Peggy Steunenberg

Telephone No.: (41-22) 338.83.38

Copy for the designated Office (DO/US)

TENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

COMMUNICATION IN CASES FOR WHICH NO OTHER FORM IS APPLICABLE

To:
RO: EP

Date of mailing (*day/month/year*) 04 September 2000 (04.09.00)	
Applicant's or agent's file reference M/41157	**REPLY DUE** see paragraph 1 below
International application No. PCT/EP00/03171	International filing date (*day/month/year*) 10 April 2000 (10.04.00)
Applicant DE NORA FUEL CELLS S.P.A.	

1. ☐ REPLY DUE within _____ months/days from the above date of mailing

   ☐ NO REPLY DUE, however, see below

   ☒ IMPORTANT COMMUNICATION

   ☐ INFORMATION ONLY

2. COMMUNICATION:

Following the non-payment of precautionary designation fees, please note that Form PCT/IB/359 dated 13 July 2000 should be disregarded :

The only States designated are therefore those appearing originally on the request:

EP, AU, BR, CA, CN, IN, JP, KR, US.

The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland	Authorized officer Simin Baharlou
Facsimile No. (41-22) 740.14.35	Telephone No. (41-22) 338.83.38

INTERNATIONAL SEARCH REPORT

Int. ional Application No
EP 00/03171

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01M8/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H01M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 98 45889 A (MAGNET MOTOR GMBH ;KOSCHANY ARTHUR (DE); LUCAS CHRISTIAN (DE); SCH) 15 October 1998 (1998-10-15) claims 1-3,12-14; figure 1 page 7, line 4 - line 31 page 9, line 30 - line 31	1,7,8
Y		1,2,10, 13-15

-/—

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 August 2000	06/09/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	D'hondt, J

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Int. [redacted]donal Application No
[redacted]T/EP 00/03171

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	NGUYEN T V ET AL: "A WATER AND HEAT MANAGEMENT MODEL FOR PROTON-EXCHANGE-MEMBRANE FUELS CELLS" JOURNAL OF THE ELECTROCHEMICAL SOCIETY,US,ELECTROCHEMICAL SOCIETY. MANCHESTER, NEW HAMPSHIRE, vol. 140, no. 8, 1 August 1993 (1993-08-01), pages 2178-2186, XP000403645 ISSN: 0013-4651 page 2182, right-hand column, paragraph 2; figure 3 abstract	1
Y		1,2,10, 13-15
Y	WO 98 33221 A (LYNNTECH INC) 30 July 1998 (1998-07-30) page 11, line 19 -page 12, line 21; figure 14A column 6, line 22 - line 24	1,2,10, 13-15
X	US 4 769 297 A (REISER CARL A ET AL) 6 September 1988 (1988-09-06) column 3, line 13 - line 16; claim 1; figure 1 column 4, line 67 -column 5, line 2 column 5, line 39 - line 50	1
X	EP 0 743 693 A (SANYO ELECTRIC CO) 20 November 1996 (1996-11-20) column 2, line 45 -column 3, line 2 column 4, line 43 - line 59; figures 3,4 column 5, line 52 -column 6, line 17 column 6, line 41 - line 54 column 11, line 11 - line 18	1
X	EP 0 301 757 A (UNITED TECHNOLOGIES CORP) 1 February 1989 (1989-02-01) column 3, line 56 -column 4, line 3; figure 1	1
P,X	US 6 015 633 A (ACKER WILLIAM P ET AL) 18 January 2000 (2000-01-18) claims 1-3,6,19; figures 2,7,8,10,15 column 5, line 57 -column 6, line 11 column 10, line 44 -column 11, line 23 column 13, line 35 - line 57 column 8, line 7 - line 11	1,7
P,X	WO 99 60640 A (VON HELMOLT RITTMAR ;MUND KONRAD (DE); GENENGER BERND (DE); LUFT G) 25 November 1999 (1999-11-25) page 3, line 10 - line 14; claims 1,4,5 column 4, line 1 - line 7	1

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INTERNATIONAL SEARCH REPORT

Int[illegible]ional Application No
[illegible]T/EP 00/03171

C.(Continuation) DOCUMENTS C[illegible]ERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 328 115 A (INT FUEL CELLS CORP) 16 August 1989 (1989-08-16) claim 1; figure 1	1
A	EP 0 817 297 A (DE NORA SPA) 7 January 1998 (1998-01-07)	

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/EP 00/03171

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9845889 A	15-10-1998	EP 0985239 A	15-03-2000
WO 9833221 A	30-07-1998	AU 6648198 A	18-08-1998
		EP 0963614 A	15-12-1999
US 4769297 A	06-09-1988	NONE	
EP 0743693 A	20-11-1996	JP 8315839 A	29-11-1996
		CA 2171380 A	19-11-1996
		DE 69602805 D	15-07-1999
		DE 69602805 T	27-04-2000
		US 5958613 A	28-09-1999
EP 0301757 A	01-02-1989	US 4795683 A	03-01-1989
		CA 1297940 A	24-03-1992
		DE 3869009 A	16-04-1992
		JP 1140562 A	01-06-1989
US 6015633 A	18-01-2000	NONE	
WO 9960640 A	25-11-1999	NONE	
EP 0328115 A	16-08-1989	US 4824741 A	25-04-1989
		CA 1309127 A	20-10-1992
		DE 68907741 D	02-09-1993
		DE 68907741 T	10-03-1994
		JP 1309263 A	13-12-1989
		JP 2057217 C	23-05-1996
		JP 7095447 B	11-10-1995
EP 0817297 A	07-01-1998	IT MI961293 A	29-12-1997
		AU 2478897 A	15-01-1998
		BR 9703725 A	27-10-1998
		CA 2207425 A	26-12-1997
		CZ 9701998 A	18-03-1998
		JP 10055805 A	24-02-1998
		NO 972774 A	19-12-1997
		SG 63718 A	30-03-1999
		SK 87097 A	14-02-2000
		US 6022634 A	08-02-2000

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To:

Kinzebach, Werner
Reitstötter, Kinzebach & Partner
Patentanwälte
Sternwartstrasse 4
81679 München
ALLEMAGNE

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Rule 71.1)

Date of mailing *(day/month/year)*	10.08.2001
Applicant's or agent's file reference M/41157	**IMPORTANT NOTIFICATION**

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/EP00/03171	10/04/2000	21/04/1999

Applicant
DE NORA FUEL CELLS S.P.A.

1. The applicant is hereby notified that this International Preliminary Examining Authority transmits herewith the international preliminary examination report and its annexes, if any, established on the international application.

2. A copy of the report and its annexes, if any, is being transmitted to the International Bureau for communication to all the elected Offices.

3. Where required by any of the elected Offices, the International Bureau will prepare an English translation of the report (but not of any annexes) and will transmit such translation to those Offices.

4. **REMINDER**

   The applicant must enter the national phase before each elected Office by performing certain acts (filing translations and paying national fees) within 30 months from the priority date (or later in some Offices) (Article 39(1)) (see also the reminder sent by the International Bureau with Form PCT/IB/301).

   Where a translation of the international application must be furnished to an elected Office, that translation must contain a translation of any annexes to the international preliminary examination report. It is the applicant's responsibility to prepare and furnish such translation directly to each elected Office concerned.

   For further details on the applicable time limits and requirements of the elected Offices, see Volume II of the PCT Applicant's Guide.

Name and mailing address of the IPEA/	Authorized officer
European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Krage, D Tel.+49 89 2399-7530

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
M/41157		
International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/EP00/03171	10/04/2000	21/04/1999
International Patent Classification (IPC) or national classification and IPC H01M8/04		
Applicant DE NORA FUEL CELLS S.P.A.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 6 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 3 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   - VI ☒ Certain documents cited
   - VII ☐ Certain defects in the international application
   - VIII ☐ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
20/11/2000	10.08.2001
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Haering, C Telephone No. +49 89 2399 8010

Form PCT/IPEA/409 (cover sheet) (January 1994)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/EP00/03171

I. Basis of the report

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:
Description, pages:

1-20	as originally filed				

Claims, No.:

1-20	as received on	30/04/2001	with letter of	30/04/2001	

Drawings, sheets:

1/10-10/10	as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available or furnished to this Authority in the following language: , which is:

   - ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
   - ☐ the language of publication of the international application (under Rule 48.3(b)).
   - ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   - ☐ contained in the international application in written form.
   - ☐ filed together with the international application in computer readable form.
   - ☐ furnished subsequently to this Authority in written form.
   - ☐ furnished subsequently to this Authority in computer readable form.
   - ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   - ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

   - ☐ the description, pages:
   - ☐ the claims, Nos.:

☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

(Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-20
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1-20
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-20
	No:	Claims	

2. Citations and explanations
see separate sheet

VI. Certain documents cited

1. Certain published documents (Rule 70.10)

and / or

2. Non-written disclosures (Rule 70.9)

see separate sheet

Amendments:

The amendment consisted in adding the subject-matter of claim 2 to the subject-matter of claim 1.

Re Item V

Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. ***Disclosures:***

D1: WO 98 33221 A
D2: US-A-4 769 297
D3: EP-A-0 328 115
D4: EP-A-0 743 693
D5: EP-A-0 301 757
D6: WO 98 45889 A
D7: NGUYEN ET AL: 'A WATER AND HEAT MANAGEMENT MODEL FOR PROTON-EXCHANGE-MEMBRANE FUELS CELLS' J. ELECTROCHEM. SOC., vol. 140, no. 8, 1 August 1993, pages 2178-2186, XP000403645
D8: US-A-6 015 633
D9: WO 99 60640 A
D10 EP-A-0 817 297

1.1. Document D1 discloses a stack of polymeric membrane fuel cells comprising, at least an injection point for injecting water flow inside at least one compartment of the cells, said flow providing **only for the humidification, but not for the removal of generated heat** (page 5, lines 15 to 20 + page 12, lines 1 to 16). For the cooling, some "separate" hollow tubes are considered in D1 (p.12, l.9-16). Thus, D1 is not considered to be of particular relevance.

1.2. Document D2 discloses a stack of polymeric membrane fuel cells comprising,

a. at least an injection point for injecting water flow inside at least one compartment of the cells, said flow providing for the humidification and the removal of generated heat (Abstract, claim 1 and column 5, lines 39 to 50).

b. However, **D2 does not disclose** any electrically and thermally conductive

reticulated element between the electrodes and the bipolar plates. Instead, **D2 discloses some porous flow field plates, provided with grooves**, which define the flow field path (c.3, l.37-58).

1.3. Document D3 discloses a stack of polymeric membrane fuel cells similar to the one of D2 (c.1, l.39-45).

1.4. In documents D4 to D7, a stack of polymeric membrane fuel cells is disclosed, but no electrically and thermally conductive reticulated element, disposed between the electrodes and the bipolar plates, is mentioned.

1.5. Document D10, from the same applicant, discloses the same construction of the stack, but without any injection point as claimed in claim 1. Thus, this document is not considered to be of particular relevance.

2. Novelty:

2.1. The subject-matter of **claim 1** is novel under Article 33(1) and (2) PCT with regard of D1 to D10, since none of the documents relates to a solid polymer electrolyte fuel cell comprising an electrically and thermally conductive reticulated element, which distributes the water flow through the whole volume occupied by the gaseous reactants (see 1.1. to 1.5. and Item VI).

2.2. As a consequence, the subject-matters of the dependent claims 2 to 20 are considered to be novel too.

3. Inventive step:

3.1. Document D2 (or D3), which is considered to represent the most relevant state of the art, discloses (cf. 1.2. and 1.3.) a porous flow field plate from which the subject-matter of claim 1 differs in that the element distributes the water flow through the whole volume occupied by the gaseous reactants.

3.2. The problem to be solved by the present invention may therefore be regarded as improving heat removal, even when operating at large current densities, combined

with a sufficient humidifying.

3.3. This problem is solved by intercaling an electrically, thermally, reticulated element between the electrodes and the bipolar plates according to claim 1, which is capable of distributing water through the whole volume occupied by gaseous reactants.

3.4. Moreover, no porosity is indicated in D2 or D3. And given the fact that grooves in the porous plates define the flow field of the gaseous reactants, it is evident for the person skilled that the porosity of the plates is rather low. And, any residual porosity will further decrease during operation when the plates are soaked wiht water. Thus, neither D2 nor D3 suggest to provide a volume in a fuel cell compartment where gaseous reactants, water, water wapor and the reticulated element can interact.

3.5. Thus, the subject-matter of claim 1 is considered as inventive too under Article 33(1) and (3) PCT.

3.6. As a consequence, the subject-matters of dependent claims are also considered as novel and inventive.

Re Item VI

Certain documents cited

Documents D8 and D9 belong to the state of the art for questions of novelty under Article 54(3) EPC, and could therefore be used in the regional phase;

a. however, document D8 is not novelty destroying for the subject-matter of claims 1, because the reticulated element, which distribute the water flow, distribute it only at the turns of the flow channels of the flow filed plates, and not through the whole volume occupied by the gaseous reactants; and

b. document D9 is not relevant for the question of novelty since no reticulated element for the distribution of water and gas reactants is mentioned.

CLAIMS

1. A stack of polymeric membrane fuel cells fed with gaseous reactants, wherein said membrane separates an anodic compartment from a cathodic compartment comprising bipolar plates, gaskets optionally provided with channels for feeding and discharging fluids, porous electrodes, catalytic layers interposed between the membranes and the electrodes, manifolds for feeding the flow of reactants, manifolds for the discharge of the unconverted portions of the reactants, of the inerts and of the produced water, and at least an injection point connecting a hydraulic circuit for injecting a water flow inside at least one compartment of the cells, characterised in that said water flow provides contemporaneously for the humidification of the membranes and for the removal of the generated heat.

2. The stack of claim 1 characterised in that the at least one compartment of the cells fed with the reactants and water coming from the injection point comprises an electrically and thermally conductive reticulated element interposed between the electrodes and the bipolar plates, which distributes said water flow through the whole volume occupied by the gaseous reactants.

3. The stack of claim 2 characterised in that the injection point of water is positioned outside said at least one compartment.

4. The stack of claim 3 characterised in that said injection point of water is positioned at the inlet of the manifold for feeding the flow of reactants.

5. The stack of claim 4 characterised in that said manifold for feeding the flow of reactants is a lower manifold.

6. The stack of claim 5 characterised in that said stack is rotated with respect to its main axis and said manifold is in the lowest position.

7. The stack of the preceding claims characterised in that only one of the compartments of the cells is fed with water.

8. The stack of claim 7 characterised in that said only one compartment fed with water is the cathodic compartment.

9. The stack of claim 3 characterised in that said injection point of water is positioned in channels formed in the gaskets, downstream the manifold for feeding the flow of reactants.

10. The stack of claim 2 characterised in that said injection point of water is positioned inside the cells.

11. The stack of claim 9 characterised in that the orientation of the injection of water is substantially parallel to directions of the reactants flow.

12. The stack of claim 9 characterised in that the orientation of the injection of water is substantially orthogonal to the direction of the reactants flow.

13. The stack of claim 2 characterised in that said reticulated element is deformable by cold-pressing.

14. The stack of claim 13 characterised in that said reticulated element deformable by cold-pressing is a metal foam.

15. The stack of claim 14 characterised in that said metal foam contains nickel.

16. The stack of claim 13 characterised in that said reticulated element comprises at least one depression for water distribution.

17. The stack of claim 16 characterised in that said at l ast one depression is obtained by cold-pressing.

18. The stack of claim 16 characterised in that the orientation of said at least one depression is substantially parallel to the direction of the reactant flow.

19. The stack of claim 18 characterised in that said depressions have the form of a serpentine.

20. The stack of claim 16 characterised in that the orientation of said at least one depression is substantially orthogonal to the direction of the reactant flow .

21. The stack of claim 20 characterised in that said depressions are disposed according to an offset double comb-shaped geometry.

INTERNATIONAL SEARCH REPORT

Intl Application No
PCT/EP 00/03171

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01M8/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H01M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 98 45889 A (MAGNET MOTOR GMBH ;KOSCHANY ARTHUR (DE); LUCAS CHRISTIAN (DE); SCH) 15 October 1998 (1998-10-15) claims 1-3,12-14; figure 1 page 7, line 4 - line 31 page 9, line 30 - line 31	1,7,8
Y		1,2,10, 13-15

-/—

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 August 2000	06/09/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	D'hondt, J

Form PCT/ISA/210 (second sheet) (July 1992)

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	NGUYEN T V ET AL: "A WATER AND HEAT MANAGEMENT MODEL FOR PROTON-EXCHANGE-MEMBRANE FUELS CELLS" JOURNAL OF THE ELECTROCHEMICAL SOCIETY,US,ELECTROCHEMICAL SOCIETY. MANCHESTER, NEW HAMPSHIRE, vol. 140, no. 8, 1 August 1993 (1993-08-01), pages 2178-2186, XP000403645 ISSN: 0013-4651 page 2182, right-hand column, paragraph 2; figure 3 abstract	1
Y		1,2,10, 13-15
Y	WO 98 33221 A (LYNNTECH INC) 30 July 1998 (1998-07-30) page 11, line 19 -page 12, line 21; figure 14A column 6, line 22 - line 24	1,2,10, 13-15
X	US 4 769 297 A (REISER CARL A ET AL) 6 September 1988 (1988-09-06) column 3, line 13 - line 16; claim 1; figure 1 column 4, line 67 -column 5, line 2 column 5, line 39 - line 50	1
X	EP 0 743 693 A (SANYO ELECTRIC CO) 20 November 1996 (1996-11-20) column 2, line 45 -column 3, line 2 column 4, line 43 - line 59; figures 3,4 column 5, line 52 -column 6, line 17 column 6, line 41 - line 54 column 11, line 11 - line 18	1
X	EP 0 301 757 A (UNITED TECHNOLOGIES CORP) 1 February 1989 (1989-02-01) column 3, line 56 -column 4, line 3; figure 1	1
P,X	US 6 015 633 A (ACKER WILLIAM P ET AL) 18 January 2000 (2000-01-18) claims 1-3,6,19; figures 2,7,8,10,15 column 5, line 57 -column 6, line 11 column 10, line 44 -column 11, line 23 column 13, line 35 - line 57 column 8, line 7 - line 11	1,7
P,X	WO 99 60640 A (VON HELMOLT RITTMAR ;MUND KONRAD (DE); GENENGER BERND (DE); LUFT G) 25 November 1999 (1999-11-25) page 3, line 10 - line 14; claims 1,4,5 column 4, line 1 - line 7	1

-/--

INTERNATIONAL SEARCH REPORT

Int[illegible]l Application No
PCT/EP 00/03171

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 328 115 A (INT FUEL CELLS CORP) 16 August 1989 (1989-08-16) claim 1; figure 1	1
A	EP 0 817 297 A (DE NORA SPA) 7 January 1998 (1998-01-07)	

INTERNATIONAL SEARCH REPORT

Information on patent family members

Int. Application No
PCT/EP 00/03171

Patent document cited in search report	Publication date	Patent family member(s)	Publication dat
WO 9845889 A	15-10-1998	EP 0985239 A	15-03-2000
WO 9833221 A	30-07-1998	AU 6648198 A	18-08-1998
		EP 0963614 A	15-12-1999
US 4769297 A	06-09-1988	NONE	
EP 0743693 A	20-11-1996	JP 8315839 A	29-11-1996
		CA 2171380 A	19-11-1996
		DE 69602805 D	15-07-1999
		DE 69602805 T	27-04-2000
		US 5958613 A	28-09-1999
EP 0301757 A	01-02-1989	US 4795683 A	03-01-1989
		CA 1297940 A	24-03-1992
		DE 3869009 A	16-04-1992
		JP 1140562 A	01-06-1989
US 6015633 A	18-01-2000	NONE	
WO 9960640 A	25-11-1999	NONE	
EP 0328115 A	16-08-1989	US 4824741 A	25-04-1989
		CA 1309127 A	20-10-1992
		DE 68907741 D	02-09-1993
		DE 68907741 T	10-03-1994
		JP 1309263 A	13-12-1989
		JP 2057217 C	23-05-1996
		JP 7095447 B	11-10-1995
EP 0817297 A	07-01-1998	IT MI961293 A	29-12-1997
		AU 2478897 A	15-01-1998
		BR 9703725 A	27-10-1998
		CA 2207425 A	26-12-1997
		CZ 9701998 A	18-03-1998
		JP 10055805 A	24-02-1998
		NO 972774 A	19-12-1997
		SG 63718 A	30-03-1999
		SK 87097 A	14-02-2000
		US 6022634 A	08-02-2000

FORM PTO-1390 (REV 5-93) — DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE — ATTY'S DOCKET NUMBER

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTY'S DOCKET NUMBER: 267.160

U.S. APPLICATION NO. (If known, see 37 C.F.R.1.5): 09/937973

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/EP00/03171	April 10, 2000	April 21, 1999

TITLE OF INVENTION: FUEL CELL...LIQUID WATER

APPLICANT(S) FOR DO/EO/US: M. BRAMBILLA et al

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☐ This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☐ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ has been transmitted by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US)
6. ☒ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
   a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ have been transmitted by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☐ have not been made and will not be made.
8. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern other document(s) or information included:

11. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A FIRST preliminary amendment.
    ☐ A SECOND or SUBSEQUENT preliminary amendment.
14. ☐ A substitute specification.
15. ☐ A change of power of attorney and/or address letter.
16. ☒ Other items or information: Also enclosed: PTO Form-2038, 1449 forms,cited refs, PCT/EO/101 7/98 form, Form PCT/IB/301 7/98 (2 pages), Form PCT/IB/304 7/98 form, Form PCT/IB/306 3/94) form, Notification of transmittal of International Preliminary Examination Report

410 Rec'd PCT/PTO 01 OCT 2001

U.S. APPLICATION NO (If known, see 37 CFR 1.5) 09/937973	INTERNATIONAL APPLICATION NO PCT/EP00/03171	ATTORNEY'S DOCKET NUMBER 267.160

17. ☒ The following fees are submitted:	CALCULATIONS	PTO USE ONLY
Basic National Fee (37 CFR 1.492(a)(1)-(5)): Search Report has been prepared by the EPO or JPO $830.00	1040.00	
International preliminary examination fee paid to USPTO (37 CFR 1.482) $640.00		
No international preliminary examination fee paid to USPTO (37 CFR 1.482) but international search fee paid to USPTO (37 CFR 1.445(a)(2)).. $710.00		
Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37CFR 1.445(a)(2)) paid to USPTO..... $950.00		
International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4)..... $90.00		
ENTER APPROPRIATE BASIC FEE AMOUNT =	$ 1040.00	
Surcharge of $130.00 for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(e)).	$	

Claims	Number Filed	Number Extra	Rate	
Total Claims	1 -20 =	0	X $22.00	$ 0
Independent Claims	20 -3 =	0	X $74.00	$ 0
Multiple dependent claims(s) (if applicable)		0	+ $230.00	$ 0
TOTAL OF ABOVE CALCULATIONS =				$ 1040.00
Reduction by 1/2 for filing by small entity, if applicable. Verified Small Entity statement must also be filed. (Note 37 CFR 1.9, 1.27, 1.28).				$
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Processing fee of $130.00 for furnishing the English translation later the ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(f)). +				$
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TOTAL FEES ENCLOSED =				$ 1080.00
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b. ☐ Please charge my Deposit Account No. _____ in the amount of $_____ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 02-2038. A duplicate copy of this sheet is enclosed.

X PTO Form-2038 authoruzing fees is enclosed herewith.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

Bierman, Muserlian and Lucas
600 Third Avenue
New York, N.Y. 10016

SIGNATURE

Charles A. Muserlian
NAME

19,683
REGISTRATION NUMBER

Form PTO-1390 (REV 5-93)

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WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 : H01M 8/04 — A1

(11) International Publication Number: WO 00/63992

(43) International Publication Date: 26 October 2000 (26.10.00)

(21) International Application Number: PCT/EP00/03171

(22) International Filing Date: 10 April 2000 (10.04.00)

(30) Priority Data:
MI99A000829 21 April 1999 (21.04.99) IT

(71) Applicant *(for all designated States except US)*: DE NORA FUEL CELLS S.P.A. [IT/IT]; Via Bistolfi, 35, I–20134 Milan (IT).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: BRAMBILLA, Massimo [IT/IT]; Via Piave, 8, I–20060 Bussero (IT). MAZZUCCHELLI, Gabriele [IT/IT]; Via Paolo Sarpi, 9, I–20154 Milan (IT).

(74) Agents: KINZEBACH, Werner et al.; Reitstötter, Kinzebach & Partner, Sternwartstrasse 4, D–81679 München (DE).

(81) Designated States: AU, BR, CA, CN, IN, JP, KR, US, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: FUEL CELL WITH COOLING SYSTEM BASED ON DIRECT INJECTION OF LIQUID WATER

(57) Abstract

The invention relates to a stack of polymeric membrane fuel cells, wherein the removal of the heat generated by the production of electric energy and the humidification of the ion exchange membranes used as electrolytes are obtained by the direct injection of a water flow coming from a single hydraulic circuit. The stack thus produced is more compact, less expensive and easier to operate.

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REQUEST

The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty.

For receiving Office use only

International Application No. PCT/EP 00/03171

International Filing Date 10 APR 2000 (10.04.2000)

EUROPEAN PATENT OFFICE
PCT INTERNATIONAL APPLICATION

Name of receiving Office and "PCT International Application"

Applicant's or agent's file reference *(if desired) (12 characters maximum)* M/41157

Box No. I TITLE OF INVENTION

FUEL CELL WITH COOLING SYSTEM BASED ON DIRECT INJECTION OF LIQUID WATER

Box No. II APPLICANT

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

DE NORA FUEL CELLS S.p.A.
Via Bistolfi 35
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Italy

☐ This person is also inventor.

Telephone No.

Facsimile No.

Teleprinter No.

State *(that is, country)* of nationality: IT

State *(that is, country)* of residence: IT

This person is applicant for the purposes of: ☐ all designated States ☒ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

Box No. III FURTHER APPLICANT(S) AND/OR (FURTHER) INVENTOR(S)

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

BRAMBILLA, Massimo
Via Piave 8
I-20060 Bussero
Italy

This person is:

☐ applicant only

☒ applicant and inventor

☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality: IT

State *(that is, country)* of residence: IT

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

☒ Further applicants and/or (further) inventors are indicated on a continuation sheet.

Box No. IV AGENT OR COMMON REPRESENTATIVE; OR ADDRESS FOR CORRESPONDENCE

The person identified below is hereby/has been appointed to act on behalf of the applicant(s) before the competent International Authorities as: ☒ agent ☐ common representative

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

Reitstötter, Kinzebach & Partner
Werner Kinzebach . Peter Riedl . Georg Schweiger .
J. Uwe Müller
Sternwartstr. 4
D-81679 München
Germany

Telephone No. 089/99 83 97-0

Facsimile No. 089/987304

Teleprinter No.

☐ **Address for correspondence:** Mark this check-box where no agent or common representative is/has been appointed and the space above is used instead to indicate a special address to which correspondence should be sent.

Continuation of Box No. III **FURTHER APPLICANT(S) AND/OR (FURTHER) INVENTOR(S)**

If none of the fo[illegible]ng sub-boxes is used, this sheet should not be i[illegible]ed in the request.

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

MAZZUCCHELLI, Gabriele
Via Paolo Sarpi 9
I-20154 Milan
Italy

This person is:

☐ applicant only

☒ applicant and inventor

☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality: IT

State *(that is, country)* of residence: IT

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

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Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

This person is:

☐ applicant only

☐ applicant and inventor

☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality:

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This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

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Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

This person is:

☐ applicant only

☐ applicant and inventor

☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality:

State *(that is, country)* of residence:

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

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Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

This person is:

☐ applicant only

☐ applicant and inventor

☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality:

State *(that is, country)* of residence:

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

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☐ Further applicants and/or (further) inventors are indicated on another continuation sheet.

See Notes to the request form

Box No.V DESIGNATION OF STATES

The following designations are hereby made under Rule 4.9(a) *(mark the applicable check boxes; at least one must be marked)*:

Regional Patent

☐ **AP** **ARIPO Patent:** GH Ghana, GM Gambia, KE Kenya, LS Lesotho, MW Malawi, SD Sudan, SL Sierra Leone, SZ Swaziland, TZ United Republic of Tanzania, UG Uganda, ZW Zimbabwe, and any other State which is a Contracting State of the Harare Protocol and of the PCT

☐ **EA** **Eurasian Patent:** AM Armenia, AZ Azerbaijan, BY Belarus, KG Kyrgyzstan, KZ Kazakhstan, MD Republic of Moldova, RU Russian Federation, TJ Tajikistan, TM Turkmenistan, and any other State which is a Contracting State of the Eurasian Patent Convention and of the PCT

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☐ **OA** **OAPI Patent:** BF Burkina Faso, BJ Benin, CF Central African Republic, CG Congo, CI Côte d'Ivoire, CM Cameroon, GA Gabon, GN Guinea, GW Guinea-Bissau, ML Mali, MR Mauritania, NE Niger, SN Senegal, TD Chad, TG Togo, and any other State which is a member State of OAPI and a Contracting State of the PCT *(if other kind of protection or treatment desired, specify on dotted line)* .....

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☐ **TT** Trinidad and Tobago .....
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☐ **UA** Ukraine .....
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Precautionary Designation Statement: In addition to the designations made above, the applicant also makes under Rule 4.9(b) all other designations which would be permitted under the PCT except any designation(s) indicated in the Supplemental Box as being excluded from the scope of this statement. The applicant declares that those additional designations are subject to confirmation and that any designation which is not confirmed before the expiration of 15 months from the priority date is to be regarded as withdrawn by the applicant at the expiration of that time limit. *(Confirmation (including fees) must reach the receiving Office within the 15-month time limit.)*

Box No. VI PRIORITY CLAIM ☐ Further priority claims are indicated in the Supplemental Box.

Filing date of earlier application (day/month/year)	Number of earlier application	Where earlier application is: national application: country	regional application:* regional Office	international application: receiving Office
item (1) 21 April 1999 (21.04.99)	MI99A 000829	Italy		
item (2)				
item (3)				

☐ The receiving Office is requested to prepare and transmit to the International Bureau a certified copy of the earlier application(s) *(only if the earlier application was filed with the Office which for the purposes of the present international application is the receiving Office)* identified above as item(s): _____

* *Where the earlier application is an ARIPO application, it is mandatory to indicate in the Supplemental Box at least one country party to the Paris Convention for the Protection of Industrial Property for which that earlier application was filed (Rule 4.10(b)(ii)). See Supplemental Box.*

Box No. VII INTERNATIONAL SEARCHING AUTHORITY

Choice of International Searching Authority (ISA) *(if two or more International Searching Authorities are competent to carry out the international search, indicate the Authority chosen; the two-letter code may be used):* ISA /

Request to use results of earlier search; reference to that search *(if an earlier search has been carried out by or requested from the International Searching Authority):*

Date *(day/month/year)* Number Country *(or regional Office)*

Box No. VIII CHECK LIST; LANGUAGE OF FILING

This international application contains the following **number of sheets:**

request	:	4
description (excluding sequence listing part)	:	20
claims	:	3
abstract	:	1
drawings	:	10
sequence listing part of description	:	
Total number of sheets	:	38

This international application is **accompanied by** the item(s) marked below:

1. ☒ fee calculation sheet
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4. ☐ statement explaining lack of signature
5. ☒ priority document(s) identified in Box No. VI as item(s):
6. ☐ translation of international application into (language):
7. ☐ separate indications concerning deposited microorganism or other biological material
8. ☐ nucleotide and/or amino acid sequence listing in computer readable form
9. ☒ other *(specify)*: Deed of Assignment for the priority appln.

Figure of the drawings which should accompany the abstract:

Language of filing of the international application: English

Box No. IX SIGNATURE OF APPLICANT OR AGENT

Next to each signature, indicate the name of the person signing and the capacity in which the person signs (if such capacity is not obvious from reading the request).

Munich, April 10, 2000

(Dr. Werner Kinzebach, Patent Attorney)

For receiving Office use only

1. Date of actual receipt of the purported international application: 10 APR 2000 (10. 04. 2000)
2. Drawings: ☒ received: ☐ not received:
3. Corrected date of actual receipt due to later but timely received papers or drawings completing the purported international application:
4. Date of timely receipt of the required corrections under PCT Article 11(2):
5. International Searching Authority (if two or more are competent): ISA /
6. ☐ Transmittal of search copy delayed until search fee is paid.

For International Bureau use only

Date of receipt of the record copy by the International Bureau:

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF RECEIPT OF RECORD COPY

(PCT Rule 24.2(a))

To:

KINZEBACH, Werner
Reitstötter, Kinzebach und Partner
Sternwartstrasse 4
D-81679 München
ALLEMAGNE

Patentanwälte
Reitstötter, Kinzebach & Part.
Eing. 26. Juli 2000
Sternwartstr. 4 D-81633 München

Date of mailing (day/month/year)	IMPORTANT NOTIFICATION
04 July 2000 (04.07.00)	
Applicant's or agent's file reference	**International application No.**
M/41157	PCT/EP00/03171

The applicant is hereby notified that the International Bureau has received the record copy of the international application as detailed below.

Name(s) of the applicant(s) and State(s) for which they are applicants:

DE NORA FUEL CELLS S.P.A. (for all designated States except US)
BRAMBILLA, Massimo et al (for US)

International filing date	:	10 April 2000 (10.04.00) ✓
Priority date(s) claimed	:	21 April 1999 (21.04.99) ✓
Date of receipt of the record copy by the International Bureau	:	20 June 2000 (20.06.00)
List of designated Offices	:	

EP :AT,BE,CH,CY,DE,DK,ES,FI,FR,GB,GR,IE,IT,LU,MC,NL,PT,SE
National :AU,BR,CA,CN,IN,JP,KR,US

ATTENTION

The applicant should carefully check the data appearing in this Notification. In case of any discrepancy between these data and the indications in the international application, the applicant should immediately inform the International Bureau.

In addition, the applicant's attention is drawn to the information contained in the Annex, relating to:

- [X] time limits for entry into the national phase
- [X] confirmation of precautionary designations
- [ ] requirements regarding priority documents

A copy of this Notification is being sent to the receiving Office and to the International Searching Authority.

Th International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No. (41-22) 740.14.35

Authorized officer:

Peggy Steunenberg

Telephone No. (41-22) 338.83.38

ANNEX TO FORM PCT/IB/301

International application No.
PCT/EP00/03171

INFORMATION ON TIME LIMITS FOR ENTERING THE NATIONAL PHASE

The applicant is reminded that the "national phase" must be entered before each of the designated Offices indicated in the Notification of Receipt of Record Copy (Form PCT/IB/301) by paying national fees and furnishing translations, as prescribed by the applicable national laws.

The time limit for performing these procedural acts is **20 MONTHS** from the priority date or, for those designated States which the applicant elects in a demand for international preliminary examination or in a later election, **30 MONTHS** from the priority date, provided that the election is made before the expiration of 19 months from the priority date. Some designated (or elected) Offices have fixed time limits which expire even later than 20 or 30 months from the priority date. In other Offices an extension of time or grace period, in some cases upon payment of an additional fee, is available.

In addition to these procedural acts, the applicant may also have to comply with other special requirements applicable in certain Offices. **It is the applicant's responsibility** to ensure that the necessary steps to enter the national phase are taken in a timely fashion. Most designated Offices do not issue reminders to applicants in connection with the entry into the national phase.

For detailed information about the procedural acts to be performed to enter the national phase before each designated Office, the applicable time limits and possible extensions of time or grace periods, and any other requirements, see the relevant Chapters of Volume II of the PCT Applicant's Guide. Information about the requirements for filing a demand for international preliminary examination is set out in Chapter IX of Volume I of the PCT Applicant's Guide.

GR and ES became bound by PCT Chapter II on 7 September 1996 and 6 September 1997, respectively, and may, therefore, be elected in a demand or a later election filed on or after 7 September 1996 and 6 September 1997, respectively, regardless of the filing date of the international application. (See second paragraph above.)

Note that only an applicant who is a national or resident of a PCT Contracting State which is bound by Chapter II has the right to file a demand for international preliminary examination.

CONFIRMATION OF PRECAUTIONARY DESIGNATIONS

This notification lists only specific designations made under Rule 4.9(a) in the request. It is important to check that these designations are correct. Errors in designations can be corrected where precautionary designations have been made under Rule 4.9(b). The applicant is hereby reminded that any precautionary designations may be confirmed according to Rule 4.9(c) before the expiration of 15 months from the priority date. If it is not confirmed, it will automatically be regarded as withdrawn by the applicant. There will be no reminder and no invitation. Confirmation of a designation consists of the filing of a notice specifying the designated State concerned (with an indication of the kind of protection or treatment desired) and the payment of the designation and confirmation fees. Confirmation must reach the receiving Office within the 15-month time limit.

REQUIREMENTS REGARDING PRIORITY DOCUMENTS

For applicants who have not yet complied with the requirements regarding priority documents, the following is recalled.

Where the priority of an earlier national, regional or international application is claimed, the applicant must submit a copy of the said earlier application, certified by the authority with which it was filed ("the priority document") to the receiving Office (which will transmit it to the International Bureau) or directly to the International Bureau, before the expiration of 16 months from the priority date, provided that any such priority document may still be submitted to the International Bureau before that date of international publication of the international application, in which case that document will be considered to have been received by the International Bureau on the last day of the 16-month time limit (Rule 17.1(a)).

Where the priority document is issued by the receiving Office, the applicant may, instead of submitting the priority document, request the receiving Office to prepare and transmit the priority document to the International Bureau. Such request must be made before the expiration of the 16-month time limit and may be subjected by the receiving Office to the payment of a fee (Rule 17.1(b)).

If the priority document concerned is not submitted to the International Bureau or if the request to the receiving Office to prepare and transmit the priority document has not been made (and the corresponding fee, if any, paid) within the applicable time limit indicated under the preceding paragraphs, any designated State may disregard the priority claim, provided that no designated Office may disregard the priority claim concerned before giving the applicant an opportunity to furnish the priority document within a time limit which is reasonable under the circumstances.

Where several priorities are claimed, the priority date to be considered for the purposes of computing the 16-month time limit is the filing date of the earliest application whose priority is claimed.

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION CONCERNING SUBMISSION OR TRANSMITTAL OF PRIORITY DOCUMENT

(PCT Administrative Instructions, Section 411)

To:

KINZEBACH, Werner
Reitstötter, Kinzebach und Partner
Sternwartstrasse 4
D-81679 München
ALLEMAGNE

Date of mailing (day/month/year) 04 July 2000 (04.07.00)	
Applicant's or agent's file reference M/41157	**IMPORTANT NOTIFICATION**
International application No. PCT/EP00/03171	International filing date (day/month/year) 10 April 2000 (10.04.00)
International publication date (day/month/year) Not yet published	Priority date (day/month/year) 21 April 1999 (21.04.99)
Applicant DE NORA FUEL CELLS S.P.A. et al	

1. The applicant is hereby notified of the date of receipt (except where the letters "NR" appear in the right-hand column) by the International Bureau of the priority document(s) relating to the earlier application(s) indicated below. Unless otherwise indicated by an asterisk appearing next to a date of receipt, or by the letters "NR", in the right-hand column, the priority document concerned was submitted or transmitted to the International Bureau in compliance with Rule 17.1(a) or (b).

2. This updates and replaces any previously issued notification concerning submission or transmittal of priority documents.

3. An **asterisk(*)** appearing next to a date of receipt, in the right-hand column, denotes a priority document submitted or transmitted to the International Bureau but not in compliance with Rule 17.1(a) or (b). In such a case, **the attention of the applicant is directed** to Rule 17.1(c) which provides that no designated Office may disregard the priority claim concerned before giving the applicant an opportunity, upon entry into the national phase, to furnish the priority document within a time limit which is reasonable under the circumstances.

4. The **letters "NR"** appearing in the right-hand column denote a priority document which was not received by the International Bureau or which the applicant did not request the receiving Office to prepare and transmit to the International Bureau, as provided by Rule 17.1(a) or (b), respectively. In such a case, **the attention of the applicant is directed** to Rule 17.1(c) which provides that no designated Office may disregard the priority claim concerned before giving the applicant an opportunity, upon entry into the national phase, to furnish the priority document within a time limit which is reasonable under the circumstances.

Priority date	Priority application No.	Country or regional Office or PCT receiving Office	Date of receipt of priority document
21 Apri 1999 (21.04.99)	MI99A000829	IT	20 June 2000 (20.06.00)

The Internati nal Bureau of WIPO
34, chemin des Col mbettes
1211 G neva 20, Switz rland

Facsimile No. (41-22) 740.14.35

Authorized officer

Peggy Steunenberg

Telephone No. (41-22) 338.83.38

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

T :
KINZEBACH, Werner
Reitstötter, Kinzebach & Partner
Sternwartstrasse 4
D-81679 München
ALLEMAGNE

NOTICE INFORMING THE APPLICANT OF THE COMMUNICATION OF THE INTERNATIONAL APPLICATION TO THE DESIGNATED OFFICES

(PCT Rule 47.1(c), first sentence)

Date of mailing (day/month/year)	
26 October 2000 (26.10.00)	
Applicant's or agent's file reference M/41157	**IMPORTANT NOTICE**
International application No. PCT/EP00/03171	**International filing date** (day/month/year) 10 April 2000 (10.04.00)
Priority date (day/month/year) 21 April 1999 (21.04.99)	
Applicant DE NORA FUEL CELLS S.P.A. et al	

1. Notice is hereby given that the International Bureau has communicated, as provided in Article 20, the international application to the following designated Offices on the date indicated above as the date of mailing of this Notice:
   AU,KR,US

   In accordance with Rule 47.1(c), third sentence, those Offices will accept the present Notice as conclusive evidence that the communication of the international application has duly taken place on the date of mailing indicated above and no copy of the international application is required to be furnished by the applicant to the designated Office(s).

2. The following designated Offices have waived the requirement for such a communication at this time:
   BR,CA,CN,EP,IN,JP

   The communication will be made to those Offices only upon their request. Furthermore, those Offices do not require the applicant to furnish a copy of the international application (Rule 49.1(a-bis)).

3. Enclosed with this Notice is a copy of the international application as published by the International Bureau on
   26 October 2000 (26.10.00) under No. WO 00/63992

REMINDER REGARDING CHAPTER II (Article 31(2)(a) and Rule 54.2)

If the applicant wishes to postpone entry into the national phase until 30 months (or later in some Offices) from the priority date, **a demand for international preliminary examination** must be filed with the competent International Preliminary Examining Authority before the expiration of 19 months from the priority date.

It is the applicant's sole responsibility to monitor the 19-month time limit.

Note that only an applicant who is a national or resident of a PCT Contracting State which is bound by Chapter II has the right to file a demand for international preliminary examination.

REMINDER REGARDING ENTRY INTO THE NATIONAL PHASE (Article 22 or 39(1))

If the applicant wishes to proceed with the international application in the **national phase**, he must, within 20 months or 30 months, or later in some Offices, perform the acts referred to therein before each designated or elected Office.

For further important information on the time limits and acts to be performed for entering the national phase, see the Annex to Form PCT/IB/301 (Notification of Receipt of Record Copy) and Volume II of the PCT Applicant's Guide.

The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland	Authorized officer J. Zahra
Facsimile No. (41-22) 740.14.35	Telephone No. (41-22) 338.83.38

C ntinuati n f Form PCT/IB/308

NOTICE IN[redacted]MING THE APPLICANT OF THE COM ICATION OF THE INTERNATIONAL APPLICATION TO THE DESIGNATED OFFICES

Date of mailing (day/month/year)	IMPORTANT NOTICE
26 October 2000 (26.10.00)	
Applicant's or agent's file reference	**International application No.**
M/41157	PCT/EP00/03171

The applicant is hereby notified that, at the time of establishment of this Notice, the time limit under Rule 46.1 for making amendments under Article 19 has not yet expired and the International Bureau had received neither such amendments nor a declaration that the applicant does not wish to make amendments.

PATENT COOPERATION TREATY

PCT

Patentanwälte
Reitstötter, Kinzebach & Part.
Sternwartstr. 4 D-81633 München
Eing. 18. Dez. 2000

From the INTERNATIONAL BUREAU

NOTIFICATION OF THE RECORDING OF A CHANGE

(PCT Rule 92bis.1 and Administrative Instructions, Section 422)

KINZEBACH, Werner
Reitstötter, Kinzebach & Partner
Sternwartstrasse 4
D-81679 München
ALLEMAGNE

Date of mailing (day/month/year) 28 November 2000 (28.11.00)	
Applicant's or agent's file reference M/41157	**IMPORTANT NOTIFICATION**
International application No. PCT/EP00/03171	**International filing date** (day/month/year) 10 April 2000 (10.04.00)

1. The following indications appeared on record concerning:

[X] the applicant [ ] the inventor [ ] the agent [ ] the common representative

Name and Address	State of Nationality	State of Residence
DE NORA FUEL CELLS S.P.A. Via Bistolfi, 35 I-20134 Milan Italy	IT	IT
	Telephone No.	
	Facsimile No.	
	Teleprinter No.	

2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:

[ ] the person [X] the name [ ] the address [ ] the nationality [ ] the residence

Name and Address	State of Nationality	State of Residence
NUVERA FUEL CELLS EUROPE S.r.l. Via Bistolfi, 35 I-20134 Milan Italy		
	Telephone No.	
	Facsimile No.	
	Teleprinter No.	

3. Further observations, if necessary:

4. A copy of this notification has been sent to:

[X] the receiving Office
[ ] the International Searching Authority
[ ] the International Preliminary Examining Authority
[X] the designated Offices concerned
[ ] the elected Offices concerned
[ ] other:

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland**	Authorized officer Peggy Steunenberg
Facsimile No.: (41-22) 740.14.35	Telephone No.: (41-22) 338.83.38

Form PCT/IB/306 (March 1994) 003687859

7

09/937973

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
M/41157		
International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/EP00/03171	10/04/2000	21/04/1999
International Patent Classification (IPC) or national classification and IPC H01M8/04		
Applicant DE NORA FUEL CELLS S.P.A.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 6 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 3 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   - VI ☒ Certain documents cited
   - VII ☐ Certain defects in the international application
   - VIII ☐ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
20/11/2000	10.08.2001
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Haering, C Telephone No. +49 89 2399 8010

Form PCT/IPEA/409 (cover sheet) (January 1994)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/EP00/03171

I. Basis of the r port

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:
Description, pages:

1-20	as originally filed				

Claims, No.:

1-20	as received on	30/04/2001	with letter of	30/04/2001	

Drawings, sheets:

1/10-10/10	as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available or furnished to this Authority in the following language: , which is:

   - ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
   - ☐ the language of publication of the international application (under Rule 48.3(b)).
   - ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   - ☐ contained in the international application in written form.
   - ☐ filed together with the international application in computer readable form.
   - ☐ furnished subsequently to this Authority in written form.
   - ☐ furnished subsequently to this Authority in computer readable form.
   - ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   - ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

   - ☐ the description, pages:
   - ☐ the claims, Nos.:

☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

(Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-20
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1-20
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-20
	No:	Claims	

2. Citations and explanations
see separate sheet

VI. Certain documents cited

1. Certain published documents (Rule 70.10)

and / or

2. Non-written disclosures (Rule 70.9)

see separate sheet

Amendments:

The amendment consisted in adding the subject-matter of claim 2 to the subject-matter of claim 1.

Re Item V

Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. ***Disclosures:***

D1: WO 98 33221 A
D2: US-A-4 769 297
D3: EP-A-0 328 115
D4: EP-A-0 743 693
D5: EP-A-0 301 757
D6: WO 98 45889 A
D7: NGUYEN ET AL: 'A WATER AND HEAT MANAGEMENT MODEL FOR PROTON-EXCHANGE-MEMBRANE FUELS CELLS' J. ELECTROCHEM. SOC., vol. 140, no. 8, 1 August 1993, pages 2178-2186, XP000403645
D8: US-A-6 015 633
D9: WO 99 60640 A
D10 EP-A-0 817 297

1.1. Document D1 discloses a stack of polymeric membrane fuel cells comprising, at least an injection point for injecting water flow inside at least one compartment of the cells, said flow providing **only for the humidification, but not for the removal of generated heat** (page 5, lines 15 to 20 + page 12, lines 1 to 16). For the cooling, some "separate" hollow tubes are considered in D1 (p.12, l.9-16). Thus, D1 is not considered to be of particular relevance.

1.2. Document D2 discloses a stack of polymeric membrane fuel cells comprising,

a. at least an injection point for injecting water flow inside at least one compartment of the cells, said flow providing for the humidification and the removal of generated heat (Abstract, claim 1 and column 5, lines 39 to 50).

b. However, **D2 does not disclos** any electrically and thermally conductive

reticulated element between the electrodes and the bipolar plates. Instead, **D2 discloses some porous flow field plates, provided with grooves**, which define the flow field path (c.3, l.37-58).

1.3. Document D3 discloses a stack of polymeric membrane fuel cells similar to the one of D2 (c.1, l.39-45).

1.4. In documents D4 to D7, a stack of polymeric membrane fuel cells is disclosed, but no electrically and thermally conductive reticulated element, disposed between the electrodes and the bipolar plates, is mentioned.

1.5. Document D10, from the same applicant, discloses the same construction of the stack, but without any injection point as claimed in claim 1. Thus, this document is not considered to be of particular relevance.

2. Novelty:

2.1. The subject-matter of **claim 1** is novel under Article 33(1) and (2) PCT with regard of D1 to D10, since none of the documents relates to a solid polymer electrolyte fuel cell comprising an electrically and thermally conductive reticulated element, which distributes the water flow through the whole volume occupied by the gaseous reactants (see 1.1. to 1.5. and Item VI).

2.2. As a consequence, the subject-matters of the dependent claims 2 to 20 are considered to be novel too.

3. Inventive step:

3.1. Document D2 (or D3), which is considered to represent the most relevant state of the art, discloses (cf. 1.2. and 1.3.) a porous flow field plate from which the subject-matter of claim 1 differs in that the element distributes the water flow through the whole volume occupied by the gaseous reactants.

3.2. The problem to be solved by the present invention may therefore be regarded as improving heat removal, even when operating at large current densities, combined

with a sufficient humidifying.

3.3. This problem is solved by intercaling an electrically, thermally, reticulated element between the electrodes and the bipolar plates according to claim 1, which is capable of distributing water through the whole volume occupied by gaseous reactants.

3.4. Moreover, no porosity is indicated in D2 or D3. And given the fact that grooves in the porous plates define the flow field of the gaseous reactants, it is evident for the person skilled that the porosity of the plates is rather low. And, any residual porosity will further decrease during operation when the plates are soaked wiht water. Thus, neither D2 nor D3 suggest to provide a volume in a fuel cell compartment where gaseous reactants, water, water wapor and the reticulated element can interact.

3.5. Thus, the subject-matter of claim 1 is considered as inventive too under Article 33(1) and (3) PCT.

3.6. As a consequence, the subject-matters of dependent claims are also considered as novel and inventive.

Re Item VI

Certain documents cited

Documents D8 and D9 belong to the state of the art for questions of novelty under Article 54(3) EPC, and could therefore be used in the regional phase;

a. however, document D8 is not novelty destroying for the subject-matter of claims 1, because the reticulated element, which distribute the water flow, distribute it only at the turns of the flow channels of the flow filed plates, and not through the whole volume occupied by the gaseous reactants; and

b. document D9 is not relevant for the question of novelty since no reticulated element for the distribution of water and gas reactants is mentioned.

CLAIMS

1. A stack of polymeric membrane fuel cells fed with gaseous reactants, wherein said membrane separates an anodic compartment from a cathodic compartment comprising bipolar plates, gaskets optionally provided with channels for feeding and discharging fluids, porous electrodes, catalytic layers interposed between the membranes and the electrodes, manifolds for feeding the flow of reactants, manifolds for the discharge of the unconverted portions of the reactants, of the inerts and of the produced water, and at least an injection point connecting a hydraulic circuit for injecting a water flow inside at least one compartment of the cells, said water flow provides contemporaneously for the humidification of the membranes and for the removal of the generated heat, **characterised in that** at least one compartment of the cells fed with the reactants and water coming from the injection point comprises an electrically and thermally conductive reticulated element interposed between the electrodes and the bipolar plates, which distributes said water flow through the whole volume occupied by the gaseous reactants.

2. The stack of claim 1 characterised in that the injection point of water is positioned outside said at least one compartment.

3. The stack of claim 2 characterised in that said injection point of water is positioned at the inlet of the manifold for feeding the flow of reactants.

4. The stack of claim 3 characterised in that said manifold for feeding the flow of reactants is a lower manifold.

5. The stack of claim 4 characterised in that said stack is rotated with respect to its main axis and said manifold is in the lowest position.

6. The stack of the preceding claims characterised in that only one of the compartments of the cells is fed with water.

7. The stack of claim 6 characterised in that said only one compartment fed with water is the cathodic compartment.

8. The stack of claim 2 characterised in that said injection point of water is positioned in channels formed in the gaskets, downstream the manifold for feeding the flow of reactants.

9. The stack of claim 1 characterised in that said injection point of water is positioned inside the cells.

10. The stack of claim 8 characterised in that the orientation of the injection of water is substantially parallel to directions of the reactants flow.

11. The stack of claim 8 characterised in that the orientation of the injection of water is substantially orthogonal to the direction of the reactants flow.

12. The stack of claim 1 characterised in that said reticulated element is deformable by cold-pressing.

13. The stack of claim 12 characterised in that said reticulated element deformable by cold-pressing is a metal foam.

14. The stack of claim 13 characterised in that said metal foam contains nickel.

15. The stack of claim 12 characterised in that said reticulated element comprises at least one depression for water distribution.

16. The stack of claim 15 characterised in that said at least one depression is obtained by cold-pressing.

17. The stack of claim 15 characterised in that the orientation of said at least one depression is substantially parallel to the direction of the reactant flow.

18. The stack of claim 17 characterised in that said depressions have the form of a serpentine.

19. The stack of claim 15 characterised in that the orientation of said at least one depression is substantially orthogonal to the direction of the reactant flow .

20. The stack of claim 19 characterised in that said depressions are disposed according to an offset double comb-shaped geometry.

Dvei

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	**FOR FURTHER ACTION** see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.	
M/41157		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/EP 00/ 03171	10/04/2000	21/04/1999
Applicant		
DE NORA FUEL CELLS S.P.A.		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 4 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

   [ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

   b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

   [ ] contained in the international application in written form.

   [ ] filed together with the international application in computer readable form.

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2. [ ] **Certain claims were found unsearchable** (See Box I).

3. [ ] **Unity of invention is lacking** (see Box II).

4. With regard to the **title**,

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6. Th figure of the **drawings** to b published with the abstract is Figure No. _____

   [ ] as suggested by the applicant.

   [ ] because th applicant failed to suggest a figure.

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   [X] None of th figures.

INTERNATIONAL SEARCH REPORT

International Application No
[redacted]EP 00/03171

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01M8/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H01M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 98 45889 A (MAGNET MOTOR GMBH ;KOSCHANY ARTHUR (DE); LUCAS CHRISTIAN (DE); SCH) 15 October 1998 (1998-10-15) claims 1-3,12-14; figure 1 page 7, line 4 - line 31 page 9, line 30 - line 31	1,7,8
Y		1,2,10, 13-15

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
30 August 2000	06/09/2000

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European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	D'hondt, J

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
X	NGUYEN T V ET AL: "A WATER AND HEAT MANAGEMENT MODEL FOR PROTON-EXCHANGE-MEMBRANE FUELS CELLS" JOURNAL OF THE ELECTROCHEMICAL SOCIETY,US,ELECTROCHEMICAL SOCIETY. MANCHESTER, NEW HAMPSHIRE, vol. 140, no. 8, 1 August 1993 (1993-08-01), pages 2178-2186, XP000403645 ISSN: 0013-4651 page 2182, right-hand column, paragraph 2; figure 3 abstract	1
Y		1,2,10, 13-15
Y	WO 98 33221 A (LYNNTECH INC) 30 July 1998 (1998-07-30) page 11, line 19 -page 12, line 21; figure 14A column 6, line 22 - line 24	1,2,10, 13-15
X	US 4 769 297 A (REISER CARL A ET AL) 6 September 1988 (1988-09-06) column 3, line 13 - line 16; claim 1; figure 1 column 4, line 67 -column 5, line 2 column 5, line 39 - line 50	1
X	EP 0 743 693 A (SANYO ELECTRIC CO) 20 November 1996 (1996-11-20) column 2, line 45 -column 3, line 2 column 4, line 43 - line 59; figures 3,4 column 5, line 52 -column 6, line 17 column 6, line 41 - line 54 column 11, line 11 - line 18	1
X	EP 0 301 757 A (UNITED TECHNOLOGIES CORP) 1 February 1989 (1989-02-01) column 3, line 56 -column 4, line 3; figure 1	1
P,X	US 6 015 633 A (ACKER WILLIAM P ET AL) 18 January 2000 (2000-01-18) claims 1-3,6,19; figures 2,7,8,10,15 column 5, line 57 -column 6, line 11 column 10, line 44 -column 11, line 23 column 13, line 35 - line 57 column 8, line 7 - line 11	1,7
P,X	WO 99 60640 A (VON HELMOLT RITTMAR ;MUND KONRAD (DE); GENENGER BERND (DE); LUFT G) 25 November 1999 (1999-11-25) page 3, line 10 - line 14; claims 1,4,5 column 4, line 1 - line 7	1

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INTERNATIONAL SEARCH REPORT

International Application No
[redacted]/EP 00/03171

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 328 115 A (INT FUEL CELLS CORP) 16 August 1989 (1989-08-16) claim 1; figure 1	1
A	EP 0 817 297 A (DE NORA SPA) 7 January 1998 (1998-01-07)	

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
EP 00/03171

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9845889 A	15-10-1998	EP 0985239 A	15-03-2000
WO 9833221 A	30-07-1998	AU 6648198 A	18-08-1998
		EP 0963614 A	15-12-1999
US 4769297 A	06-09-1988	NONE	
EP 0743693 A	20-11-1996	JP 8315839 A	29-11-1996
		CA 2171380 A	19-11-1996
		DE 69602805 D	15-07-1999
		DE 69602805 T	27-04-2000
		US 5958613 A	28-09-1999
EP 0301757 A	01-02-1989	US 4795683 A	03-01-1989
		CA 1297940 A	24-03-1992
		DE 3869009 A	16-04-1992
		JP 1140562 A	01-06-1989
US 6015633 A	18-01-2000	NONE	
WO 9960640 A	25-11-1999	NONE	
EP 0328115 A	16-08-1989	US 4824741 A	25-04-1989
		CA 1309127 A	20-10-1992
		DE 68907741 D	02-09-1993
		DE 68907741 T	10-03-1994
		JP 1309263 A	13-12-1989
		JP 2057217 C	23-05-1996
		JP 7095447 B	11-10-1995
EP 0817297 A	07-01-1998	IT MI961293 A	29-12-1997
		AU 2478897 A	15-01-1998
		BR 9703725 A	27-10-1998
		CA 2207425 A	26-12-1997
		CZ 9701998 A	18-03-1998
		JP 10055805 A	24-02-1998
		NO 972774 A	19-12-1997
		SG 63718 A	30-03-1999
		SK 87097 A	14-02-2000
		US 6022634 A	08-02-2000

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(54) Title: FUEL CELL WITH COOLING SYSTEM BASED ON DIRECT INJECTION OF LIQUID WATER

(57) Abstract

The invention relates to a stack of polymeric membrane fuel cells, wherein the removal of the heat generated by the production of electric energy and the humidification of the ion exchange membranes used as electrolytes are obtained by the direct injection of a water flow coming from a single hydraulic circuit. The stack thus produced is more compact, less expensive and easier to operate.

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FUEL CELL WITH COOLING SYSTEM BASED ON DIRECT INJECTION OF LIQUID WATER

DESCRIPTION OF THE INVENTION

The present invention relates to a fuel cell, and more precisely a fuel cell using a polymeric membrane as the electrolyte.

Fuel cells are electrochemical generators of electric energy in the form of direct current; in other words, they convert the free energy of reaction of a fuel (for example a gaseous mixture containing hydrogen, or a light alcohol such as methanol or ethanol) with an oxidant (for example air or oxygen) without its complete degradation to thermal energy, and therefore without being submitted to the limitation of the Carnot cycle. To achieve the desired conversion of chemical energy to electrical energy, the fuel is oxidised at the anode of the cell, with the concurrent release of electrons and H^+ ions, while the oxidant is reduced at the cathode, where H^+ ions are consumed; the two poles of the generator must be separated by a suitable electrolyte, allowing a continuous flow of H^+ ions from the anode to the cathode, at the same time hindering the transfer of electrons from one pole to the other, thereby maximising the electrical potential difference between the two electrodes. This potential difference represents in fact the driving force of the process itself. The fuel cells are considered as an excellent alternative to the traditional systems of electric generation; especially in view of their extremely favourable environmental impact (absence of polluting emissions and noise, formation of water as the only by-product), they are used both in the field of stationary power generation of various sizes (electrical power stations, back-up power generators, etc.) as well as in the field of mobile applications (electric vehicle applications, generation of automotive energy or auxiliary energy for space, submarine and naval applications).

Th polymeric membran fuel cells offer, compared with other fuel cells, further advantages, due to their fast start-up and quick achievement of the optimum operation conditions, the high power density, the intrinsic reliability connected both to the lack of moving parts and to the absence of corrosion phenomena and severe thermal cycles; in fact, among all the fuel cells of the prior art, the polymer electrolyte fuel cells exhibit the overall lowest operating temperature (usually, 70-100°C).

The polymeric electrolyte used for this purpose is an ion-exchange membrane, and more precisely a cation-exchange membrane, that is a chemically inert polymer, partially functionalised with groups capable of undergoing acid-base hydrolysis leading to a separation of electric charge; said hydrolysis consists more precisely in the release of positive ions (cations) and in the formation of fixed negative charges on the polymer constituting the membrane. Porous electrodes are applied on the surface of the membrane, which allow for the reactants to flow therethrough up to the membrane interface. A catalyst is applied on said interface on the electrode and/or on the membrane side, such as for example platinum black, which favours the corresponding half-reaction of fuel oxidation or oxidant reduction. This arrangement provides also for the continuous flow of cations when a potential gradient is established between the two faces of the membrane and the external electric circuit is concurrently closed; being the H^+ ion the transported cation in this case, as previously mentioned, the pot ntial difference generated upon feeding a species with a lower lectrochemical potential at the anode, and a species with a higher l ctroch mical potential at the cathode, causes protonic conduction across

lectron flow (i.e. electric curr nt) across the xternal circuit, as soon as th latter is closed.

The protonic conduction is an essential condition for the operation of a fuel cell and is one of the decisive parameters to assess its efficiency. An insufficient protonic conduction causes a remarkable drop in the potential difference at the poles of the cell (cell voltage drop) once the electric circuit is closed on the external resistive load which exploits the produced electric output. This, in turn, causes an increased degradation of the energy of reaction to thermal energy and the consequent decrease of the fuel conversion efficiency.

Several cation-exchange membranes, offering optimum protonic conduction characteristics, are available on the market and are widely used in industrial fuel cells, such as for example those commercialised under the trademark Nafion® by Dupont de Nemours, U.S.A., Gore Select® by Gore, U.S.A., Aciplex® by Asahi Chemicals, Japan. All these membranes are negatively affected by an intrinsic process limitation associated with their operation mechanism: being the separation of electric charge which enables the protonic conduction set by a hydrolysis mechanism, such membranes develop their conductivity only in the presence of liquid water. Although the formation of water is an intrinsic consequence of the operation of a fuel cell, its extent results almost always insufficient to maintain the correct hydration state of the membrane, especially when operating at a sufficiently high current density.

Operation at high current density in fact involves a decr ase in the investment costs for a given power output, but also a decrease in the energy

fficiency and the generation of a higher amount of heat. The large amount of heat g nerated in a fuel cell operating at a current density of practical use (for example between 150 and 1500 mA/cm²) must be efficiently removed to permit the thermal regulation of the system, not only in view of the limited thermal stability of the ion-exchange membrane, usually unfit for operation above 100°C, but also to reduce as much as possible the evaporation of the produced water and its consequent removal by the flow of inerts and unconverted reactants from the cell. Furthermore, as the voltage at the poles of a single fuel cell is too small to allow a practical exploitation, said cells are usually connected in electrical series by means of bipolar junctions and assembled in a filter-press arrangement feeding the reactants in parallel, as illustrated in U.S. Patent No. 3,012,086. In such a fuel cell battery arrangement, usually called a "stack", the problem of heat removal is amplified with respect to the case of a single cell, wherein it is possible to take advantage of the thermal convection through the external walls. For this reason, all the designs of prior art fuel cells provide suitable hydraulic circuits for the removal of heat by thermal exchange with a circulating fluid; such fluid may be fed inside serpentines formed in the bipolar plates or in appropriate sections intercalated between single cells in electrical connection therewith; both solutions further complicate the construction of the stacks, increasing weights and volumes, thereby reducing the power density, a parameter whose maximisation is highly desired especially in the case of mobile applications.

A less burdensome solution under this aspect is described in the PCT patent application no. WO 98/28809, wherein the cooling fluid is circulated in a

peripheral section of the bipolar plate adjacent to the activ surface of the cell; how ver, in this way a transversal temperatur profile is obtained with the central area of the membrane operating at a temperature higher than that of the peripheral area, thereby establishing a thermal gradient which is potentially very dangerous for the integrity of the membrane itself.

Finally, even if the extent of the heat removal needed to set the system temperature below 100°C appears to be achievable although quite demanding, the concurrent water drain from fuel cell stacks remains too high for the produced water to maintain a sufficient hydration level of the membranes alone; the stack designs of the prior art have therefore introduced a second auxiliary system, in addition to the cooling system, which provides for injecting the required additional amount of water into the generator. This circuit generally provides for pre-humidifying the reactants at the inlet of the anode and cathode compartments of the fuel cells, for example by bubbling in liquid water or by diffusion of water vapour though suitable membranes in auxiliary cells. Also this second circuit involves an evident increase in weight, volumes and investment costs; moreover, the quantity of water to be fed to the system must be strictly controlled as an excess of liquid in the cell compartments would lead to the dramatic consequence of blocking the access of the gaseous reactants to the surface of the electrodes. The only possibility to achieve a calibration, albeit indirect, of the water supplied by the above system is acting on the temperature of the water itself and thus on its vapour pressure. This in turn brings to the need of thermostating the humidification system of the fuel cell stacks, further complicating the construction design.

A more advantageous solution to ensure a suitabl water supply to the reactant flow is disclos d in the European Patent Publication No. 316 626 where it is described the humidification of said flow through injection of atomised water thereto, for example by means of a ultrasonic aerosol generator. This solution partially mitigates the need of cooling the stack by a burdensome auxiliary heat exchange circuit, as part of the water fed thereto is vaporised inside the cell, thereby removing a substantial amount of heat. The system however is negatively affected by a basic drawback represented by the construction complexity associated with the aerosol generator which, besides being expensive, consumes a certain portion of the electric output generated by the fuel cells.

In addition, the time of permanence of water in the cell is too short to ensure at the same time the humidification of the membrane and the cooling of the stack without recurring to auxiliary circuits, especially at a high current density and with stacks comprising a high number of cells.

Furthermore, the humidification of the reactants or the addition of atomised water prior to sending said reactants to the inlet manifold may cause some water condensation or droplet formation therein, having the consequence of feeding an excess amount of water to some cells of the stack (typically those closer to the reactants inlet) and an insufficient amount to some other cells (typically those farther from the reactants inlet).

The present invention consists in a fuel cell stack comprising a reticulated el ctrically and thermally conductive material interposed between the bipolar plat and th electrodic surface as describ d for example in U.S. Patent No. 5,482,792, wher in humidification of the reactants and thermal control are

obtained by a single-circuit direct injection of a suitable flow of water which partially vaporates inside the reticulated material exploiting its high surface and its thermal conductivity which allows an efficient extraction of heat from the electrodes.

In one embodiment of the invention, the injection point of the water in the gaseous flow is positioned downstream the reactant inlet manifold.

In another embodiment, said injection point is positioned in correspondence of the periphery of the reticulated material, in areas physically separated from the ones where the reactants are fed.

In another embodiment, water is injected in correspondence of depressions formed inside the reticulated material.

In another embodiment, water is injected in correspondence of serpentine-shaped depressions provided inside the reticulated material and running along the whole surface of the same.

In another embodiment, water is injected in correspondence of offset double comb-shaped depressions provided inside the reticulated material.

The invention will be now described making reference to the figures, wherein:

Fig.1 shows a general scheme of a membrane fuel cell stack of the invention, assembled in a filter-press arrangement.

Fig. 2A shows a general scheme of a membrane fuel cell stack of the prior art, assembled in a filter-press arrangement; fig. 2B shows a bipolar plate of th prior art.

Figs. 3, 4, 5 and 6 show various types of gaskets for fuel cells.

Figs. 7, 8, 9 and 10 show various types of reticulated lements for the distribution of fluids and th connection b tween the bipolar plat s and the electrodes inside the fuel cell stacks.

Making reference to fig. 1, each elementary cell (1), which represents the repetitive unit of the modular assembly of the filter-press arrangement, comprises, proceeding from the inside to the outside, an ion-exchange membrane (2), a pair of porous electrodes (3), a pair of catalytic layers (4) formed at the interface between the membrane (2) and each of the electrodes (3), a pair of electrically conductive reticulated elements (5), a pair of gaskets (6) for the peripheral sealing, a pair of bipolar plates (7) which delimit the boundary of the elementary cell (1). The reticulated elements (5) have a minimum porosity of 50%, and perform the functions of electrically connecting the bipolar plates (7) to the electrodes (3), and distributing the gaseous reactants and the humidification water, finely subdividing the latter through all the thickness of the reticulated element (5) and thus favouring the evaporation inside the whole volume of the chamber delimited by the bipolar plate (7) and the electrode (3). Suitable apertures on the peripheral area of the bipolar plates (7) and of the gaskets (6) form, upon juxtaposition of the above mentioned components, the two upper manifolds (8), only one of which is shown in the figure, which may be used to feed the reactants, and the two lower manifolds (9), which may be used for discharging the produced water, the gaseous inerts and the non-converted portion of the reactants, only on of which is shown in the figure. Alternatively, the lower manifolds (9) may be used as feeding ducts and the upper manifolds (8) as discharge ducts. It is also possible to feed one of the

two r actants through one of the upper manifolds (8), using the corresponding lower manifold (9) as the outlet, while feeding th other reactant through the other lower manifold (9), using the corresponding upper manifold (8) as the outlet.

Externally to the elementary cell (1) assembly in a filter-press arrangement, there are two end plates (10), one of which is provided with fittings for the hydraulic connection to the manifolds (8) and (9), not shown in the figure, and both of which provided with suitable holes for the tie-rods used to clamp the complete stack, also not shown in the figure. Making reference to figures 2A and 2B, each elementary cell (1'), which constitutes the repetitive unit of the modular assembly of the filter-press arrangement, comprises, proceeding from the inside to the outside, an ion-exchange membrane (2'), a pair of porous electrodes (3'), a pair of catalytic layers (4') formed at the interface between the membrane (2') and each of the electrodes (3'), a pair of planar gaskets (6') for the hydraulic sealing, a pair of bipolar plates (7') which delimit the boundary of the elementary cell (1'). The bipolar plates (7') have a ribbed profile (11), the projecting part of which ensures the electrical continuity through the stack, while the depressed part allows the circulation of gases and water. Suitable apertures in the peripheral area of the bipolar plates (7') form, upon juxtaposition of the above mentioned components, the two upper manifolds (8'), only one of which is shown in the figure, which may be used to feed the reactants, and the two lower manifolds (9'), which may be used for discharging the produced water, the gaseous inerts and th non-conv rted portion of the reactants, only one of which is shown in the figure.

Also in this case it is possible to invert the function of the lower and upper manifolds.

Externally to the elementary cell (1') assembly in a filter-press arrangement, there are two end plates (10'), one of which is provided with fittings for the hydraulic connection to the manifolds (8') and (9'), not shown in the figure, and both of which provided with suitable holes for the tie-rods that clamp the complete stack, also not shown in the figure.

Making reference to figs. 3, 4, 5 and 6, some embodiments of gaskets (6) are shown which comprise an upper hole (12), which forms the upper manifold (8), by juxtaposition in a filter-press arrangement, a lower hole (13), which forms the lower manifold (9) by juxtaposition in a filter-press arrangement, the housing (14) for the reticulated element (5) and, optionally, one or more channels for the injection of water (15).

Making reference to fig. 7A, an embodiment of the reticulated element (5), made of a flattened expanded sheet having a rhomboidal mesh is shown; in fig. 7B, a planar fine net, having a square mesh is shown.

Making reference to figs. 8, 9 and 10, some embodiments of reticulated elements (5) are shown, made of a deformable metallic material, such as a metal foam; in the embodiments of figs. 9 and 10, depressions (16) acting as preferential channels for injecting water, are formed inside said metallic material, for example by cold-pressing.

EXAMPLE 1

Two stacks, one made of 15 and one made of 30 elementary cells (1), were manufactured according to the scheme of fig. 1, and equipped with the following components:

- Ion-exchange membranes (2) Nafion 115, commercialised by Dupont de Nemours

- Electrodes (3) commercialised by E-Tek, Inc., under the trademark ELAT®, activated by a catalytic layer (4) made of platinum particles supported on active carbon, with an active surface of 200 cm^2.

- Reticulated elements (5) made of a nickel foam as shown in fig. 8, having pores comprised between 1 and 3 mm

- Gaskets (6) according to the scheme of fig. 3

- Bipolar plates (7) made of a 2 mm thick stainless steel sheet.

- Aluminum end plates (10), electrically connected to the bipolar plates (7) of the external cells, provided with current collecting sockets connected to a variable resistive load.

The stacks were connected, through suitable fittings mounted on one of the end plates (10), to the gaseous reactants supplies and to an external circuit where demineralized water, thermostated at the desired temperature by means of a heat exchanger, was circulated. Through these connections, the stacks were fed with a mixture containing 70% of hydrogen at the negative pole (anode), and with air at the positive pole (cathode), by means of the upper manifolds (8), obtained by the juxtaposition in a filter-press configuration of the upper holes (12) and the corresponding apertures in the bipolar plates (7). The same manifolds (8) were fed with a stream of demineralized water from the corresponding circuit, the flow-rate of which was regulated as needed, according to the dynamic responses of the system. The stacks were not provided with auxiliary cooling in addition to the one supplied by the evaporation of the water injected into the manifolds (8).

The stacks were operated for 12 hours at a current density of 300 mA/cm², regulating the temperature of the cells at 70°C, and monitoring the voltage of the single cells. The water flow-rate was manually regulated so as to maximise the voltage of the single cells. At the end of this manual regulation, a voltage comprised between 715 and 745 mV was detected on each cell of both stacks. In the 30 cell stack, the cells having the lowest voltage values were statistically distributed farther away from the end plate connected to the reactants and water inlets (tail cells); after the first hour of operation, the voltage of the single cells tended to remain generally constant.

The resistive load applied to the end plates (10) was then varied in order to draw a current density of 600 mA/cm² from to the two stacks; the 15 cell stack maintained a stable operation condition, with single cell voltages comprised between 600 and 670 mV, the lowest values being statistically distributed among the tail cells; the 30 cell stack was shut-down after about one hour, as the voltages exhibited by the end cells were continuously decreasing, most probably as a consequence of local overheating.

The same tests were repeated by atomising water with a ultrasonic aerosol generator, before injecting the same water to the upper manifolds (8). In all cases, no variation in the performance was observed.

COMPARATIVE EXAMPLE 1

A 15 fuel cell stack was made according to the prior art teachings, following the scheme of fig. 2.

The stack was equipped with the following components:

- Nafion 115 ion-exchange membranes (2'), commercialised by Dupont de Nemours

- ELAT® lectrod s (3') commercialised by E-Tek Inc., activated by a catalytic layer (4') made of platinum particles supported on active carbon, with an active surface of 200 cm^2.

- Planar sealing gaskets (6'), having the same thickness as that of the electrodes (3')

- Bipolar plates (7') made of a ribbed graphite sheet having a thickness of 5 mm.

- Copper end plates (10'), electrically connected to the bipolar plates (7') of the external cells, provided with a current collecting socket connected to a variable resistive load.

Similarly to the previous Example, the stack was connected, by suitable fittings provided on one of the end plates (10'), to the feeding circuit of the gaseous reactants and to an external circuit where demineralized water, thermostated at the desired temperature by means of a heat exchanger was circulated. Through these connections, the stacks were fed with a mixture containing 70% of hydrogen at the negative pole (anode), and with air at the positive pole (cathode), through the upper manifolds (8'); a flow of demineralized water was fed from the corresponding circuit to the same manifolds (8'). The stacks were not equipped with auxiliary cooling in addition to the one provided by the evaporation of the water injected into the manifolds (8'). Notwithstanding all the attempts to regulate the water flow-rate, in the same way as described for the previous examples, it was not possible to reach a current density of 300 mA/cm^2, as the voltages of some c lls, randomly distributed, tended to decrease with time due to overh ating. By d cr asing the curr nt density, it was possible to obtain a stable

operation at 70 mA/cm²; at such value, the voltages of each single cell were distributed in a range comprised between 800 and 550 mV; it was possible to increase the current density up to 100 mA/cm² when water was atomised with the ultrasonic aerosol generator of the previous Example, but it was not possible to further increase the current output. The outcome of these tests indicated a scarce uniformity of the water injection among the various cells of the stack and, inside each cell, the irregular distribution of water inside the ribbed structure; upstream atomisation of water slightly mitigates the problem, without having the same efficiency of the fine fragmentation throughout the whole volume of the cell, produced by the reticulated element of the previous Example.

EXAMPLE 2

The two stacks of Example 1 were fed with the gaseous reactants and with water through the lower manifolds (9), using the upper manifolds (8) for discharging. Under these conditions, it was possible to operate also the 30 cell stack at 600 mA/cm², even though the voltages of the five tail cells remained below 600 mV. At the same current density, the voltages of the 15 cell stack were distributed in a range comprised between 650 and 670 mV; although the maximum values were close to those relative to the previous test, where injection was carried out through the upper manifolds, the distribution of the cell voltage values resulted much more homogeneous. The explanation resides in the fact that when a plurality of cells are fed in parallel through a manifold positioned at a higher level, it is possible that part of the water be collected on the bottom of the manifold itself, subsequently falling through the inlet of the group of cells closer to the water

injection point. In the case of injection from the bottom, water does not fall into the cells being instead suctioned by the inlet gas, providing a more uniform flow inside each single cell.

EXAMPLE 3

The tests of Examples 1 and 2 were repeated feeding pure hydrogen as the fuel, closing the outlet manifold on the anode side and injecting water only to the air inlet manifold. In both cases it has been observed that the performances of the stacks were substantially the same as in the previous cases, the detected slight increases in the cells voltages being due to the increase of the fuel molar fraction. Furthermore, it has been observed that in the case of total consumption of a pure fuel at the anode (dead-end operation), it is sufficient to humidify only the flow of the oxidant.

In this case, the upstream atomisation of water with the ultrasonic aerosol generator did not produce any positive effect.

EXAMPLE 4

The 30 cell stack of the previous examples was rotated by 35° with respect to its main axis, so that for each of the gaskets (6) fed with air, the lower hole (13) was placed at a lower level with respect to its initial position, and consequently the whole lower manifold (9) on the air side was at a lower level with respect to its initial level. The stack was then fed with air from the corresponding lower manifold (9), where water was injected as in the previous examples. Pure hydrogen was fed from the corresponding lower manifold (9) to total consumption, without any humidification and closing the relevant upper manifold (8), according to a dead-end mode operation.

EXAMPLE 5

A 45 fuel cell stack was manufactured according to th prior art teachings, following the scheme of fig. 1, equipped with the following components:

- Ion-exchange membranes (2) commercialised by Gore, U.S.A. under the trademark Gore Select®,
- Electrodes (3) commercialised by E-Tek Inc, U.S.A. under the trademark ELAT®, activated with a catalytic layer (4) made of platinum particles supported on active carbon, with an active surface of 900 cm^2.
- Reticulated elements (5) made by superimposing a flattened expanded sheet, as shown in fig. 7A, against the bipolar plate (7), having a rhomboidal mesh with side length of 3 mm, and planar fine net against the electrode (3), as shown in fig. 7B, having a square mesh with side length of 1 mm; both the expanded sheet and the planar mesh were made of stainless steel AISI 316L
- Gaskets (6) according to the scheme shown in fig. 4
- Bipolar plates (7) made of 2 mm thick stainless steel sheet.
- End plates made of aluminum (10), electrically connected to the bipolar plates (7) at each end of the stack, provided with current collecting sockets connected to a variable resistive load.

The stack was connected, through suitable fittings provided on one of the end plates (10), to the feeding circuit of the gaseous reactants and to an external circuit where demineralized water, thermostated at the desired temperature by means of a heat exchanger, was circulated. Through these connections, the stacks were fed with pure hydrogen at the negative pole (anode), and with air at the positive pole (cathode), by means of the lower manifolds (9) obtained by juxtaposing the lower holes (13) and the

corresponding holes in the bipolar plates (7) in a filter-press configuration. A flow of demineralized water, whose rate was regulated as needed, according to the dynamic responses of the system, was supplied from the relevant circuit to the injection channels (15). The stack was not equipped with auxiliary cooling in addition to the one provided by the evaporation of the water fed to the injection channels (15).

The stack was operated for 12 hours at a current density of 700 mA/cm², regulating the cell temperature at 75°C and monitoring the voltages of the single cells. The water flow rate was manually regulated up to maximising the single cell voltages. At the end of this manual regulation, all the cells of the stack displayed a voltage comprised between 680 and 700 mV, which remained stable with time. This test permitted to verify that, compared to the type of gasket used in the previous examples, which determined the mixing of gas and water in the inlet manifold, the use of the gasket shown in fig. 4, wherein the mixing of the two fluids occurs in a smaller duct, downstream the inlet manifold, is more advantageous.

Also in this case it has been verified that the atomisation of the water injected in an air flow supplied to the channels (15) does not offer any beneficial effect.

EXAMPLE 6

A 45 fuel cell stack was assembled, similar to the one of the previous example with the only exception of the gaskets which corresponded to those of fig. 5. This type of design provides a separate feeding, in mutually parallel directions, of the gas and water streams, which are mixed only after the insertion into the reticulated element (5), ensuring an even more uniform

distribution of water inside the single cells. This stack, op rat d at 700 mA/cm² under the same operating conditions of Example 5, displayed cell voltage values comprised between 700 and 715 mV.

EXAMPLE 7

A 45 fuel cell stack was assembled, similar to the one of the previous example with the only exception of the gaskets, which corresponded to those of fig. 6, and the reticulated element (5), which was made of a nickel foam similar to that of Example 1. The stack was connected so as to feed the reactants from the upper manifolds (8) and to discharge the same from the lower manifolds (9). With this gasket design, the injected gas and water streams, besides being separated until after insertion into the reticulated element (5), mix in mutually orthogonal directions. In this case, in order to ensure a sufficient humidification of the upper zone of the reticulated element, the water flow was split so as to enter to a large extent into the channels (15), and to a minor extent into the upper manifolds (8), used for feeding the cells. The portion of water injected into the channels (15) was set around 90% of the total, and in any case not below 80%. This stack, operated at 700 mA/cm² under the same operating conditions of the Examples 5 and 6, displayed cell voltage values comprised between 710 and 730 mV.

EXAMPLE 8

A 45 fuel cell stack was assembled, similar to the one of Example 6 with the only exception of the reticulated element (5), which was mad of a nickel foam as shown in fig. 9. In this case, the deformability of the metal foam was xploited to produce two small channels or depressions (16) for th

preferential distribution of water in a substantially parallel direction with respect to the gas flow; said channels were in the form of serpentines which crossed the whole surface of the foam. In order to form the depressions (16), it is sufficient to cold-press a metal wire with the desired thickness into the metal foam. In this case, 3 mm wide serpentines were obtained by cold-pressing a steel wire with the same thickness. It is obviously possible to form a single serpentine (16), to be fed from a single channel (15), or also more than two serpentines. This stack, operated at 700 mA/cm² under the same operating conditions of Examples 5, 6 and 7, displayed cell voltage values comprised between 715 and 730 mV.

EXAMPLE 9

A 45 fuel cell stack was assembled, similar to the one of Example 7 with the only exception of the gaskets (6), which corresponded to those of fig. 6 and the reticulated element (5), which was made of the nickel foam illustrated in fig. 10. Also in this case, the permanent deformability of the metal foam was exploited to produce two small channels for the preferential distribution of water; in this case, however, an offset double comb-shaped geometry was chosen to create a series of parallel ducts which were fed with water in a substantially orthogonal direction with respect to the direction of the gas flow. This increases the overall pressure drop inside the reticulated element (5) and forces the gaseous reactants to follow more tortuous paths, distributing the same along the whole active surface of the cell and avoiding stagnation or depletion areas. This stack, operated at 700 mA/cm² under the same operating conditions of Examples 5, 6 and 7, displayed cell voltage values comprised between 730 and 740 mV.

Although th invention has been described making r ference to sp cific mbodiments, the latter are not intended to limit th invention, th scop of which is defined in the following appended claims.

CLAIMS

1. A stack of polymeric membrane fuel cells fed with gaseous reactants, wherein said membrane separates an anodic compartment from a cathodic compartment comprising bipolar plates, gaskets optionally provided with channels for feeding and discharging fluids, porous electrodes, catalytic layers interposed between the membranes and the electrodes, manifolds for feeding the flow of reactants, manifolds for the discharge of the unconverted portions of the reactants, of the inerts and of the produced water, and at least an injection point connecting a hydraulic circuit for injecting a water flow inside at least one compartment of the cells, characterised in that said water flow provides contemporaneously for the humidification of the membranes and for the removal of the generated heat.

2. The stack of claim 1 characterised in that the at least one compartment of the cells fed with the reactants and water coming from the injection point comprises an electrically and thermally conductive reticulated element interposed between the electrodes and the bipolar plates, which distributes said water flow through the whole volume occupied by the gaseous reactants.

3. The stack of claim 2 characterised in that the injection point of water is positioned outside said at least one compartment.

4. The stack of claim 3 characterised in that said injection point of water is positioned at the inlet of the manifold for feeding the flow of reactants.

5. The stack of claim 4 characterised in that said manifold for feeding the flow of reactants is a lower manifold.

6. The stack of claim 5 characterised in that said stack is rotated with respect to its main axis and said manifold is in the lowest position.

7. The stack of the preceding claims characterised in that only one of the compartments of the cells is fed with water.

8. The stack of claim 7 characterised in that said only one compartment fed with water is the cathodic compartment.

9. The stack of claim 3 characterised in that said injection point of water is positioned in channels formed in the gaskets, downstream the manifold for feeding the flow of reactants.

10. The stack of claim 2 characterised in that said injection point of water is positioned inside the cells.

11. The stack of claim 9 characterised in that the orientation of the injection of water is substantially parallel to directions of the reactants flow.

12. The stack of claim 9 characterised in that the orientation of the injection of water is substantially orthogonal to the direction of the reactants flow.

13. The stack of claim 2 characterised in that said reticulated element is deformable by cold-pressing.

14. The stack of claim 13 characterised in that said reticulated element deformable by cold-pressing is a metal foam.

15. The stack of claim 14 characterised in that said metal foam contains nickel.

16. The stack of claim 13 characterised in that said reticulated element comprises at least one depression for water distribution.

17. The stack of claim 16 characteris d in that said at l ast one depression is obtained by cold-pressing.

18. The stack of claim 16 characterised in that the orientation of said at least one depression is substantially parallel to the direction of the reactant flow.

19. The stack of claim 18 characterised in that said depressions have the form of a serpentine.

20. The stack of claim 16 characterised in that the orientation of said at least one depression is substantially orthogonal to the direction of the reactant flow .

21. The stack of claim 20 characterised in that said depressions are disposed according to an offset double comb-shaped geometry.

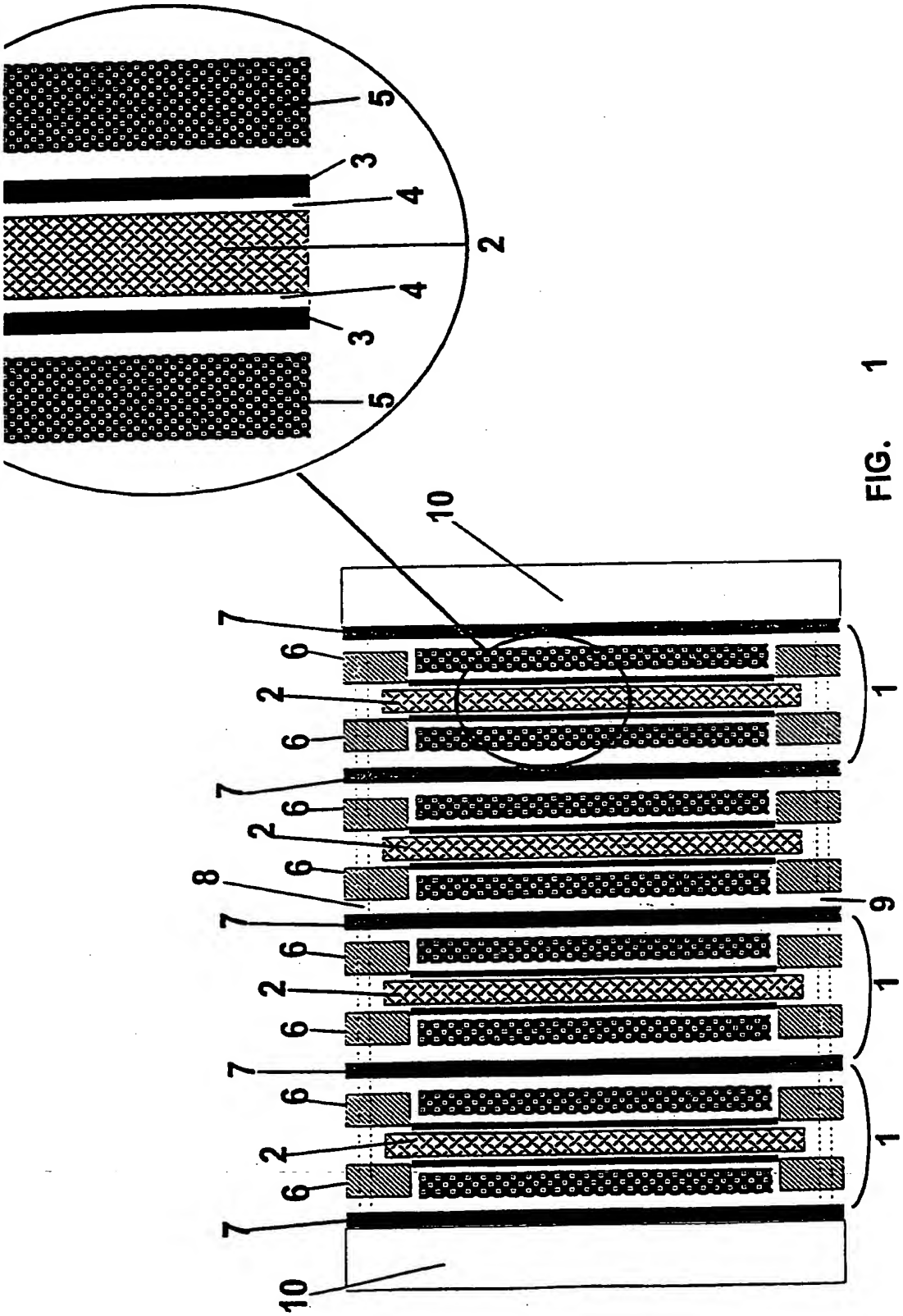


FIG. 1

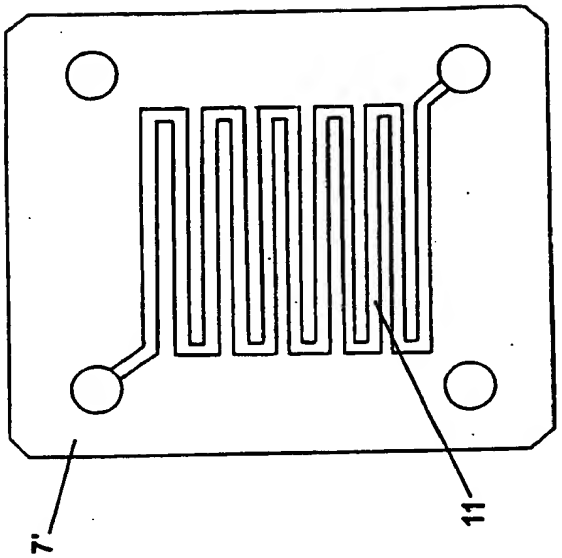


FIG. 2B

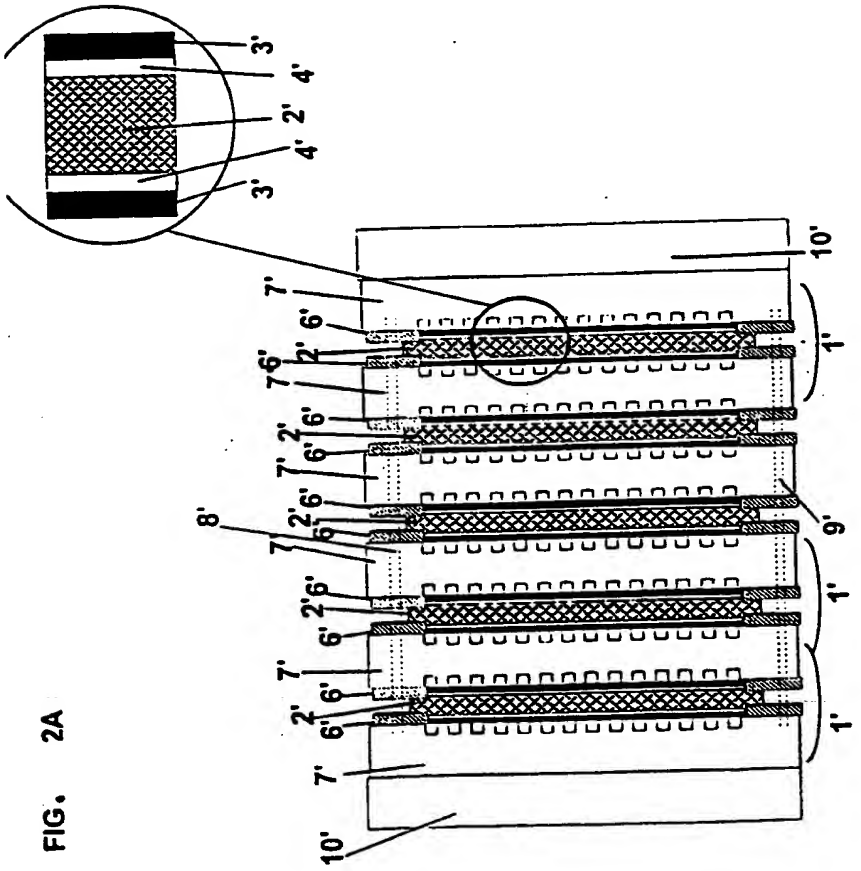


FIG. 2A

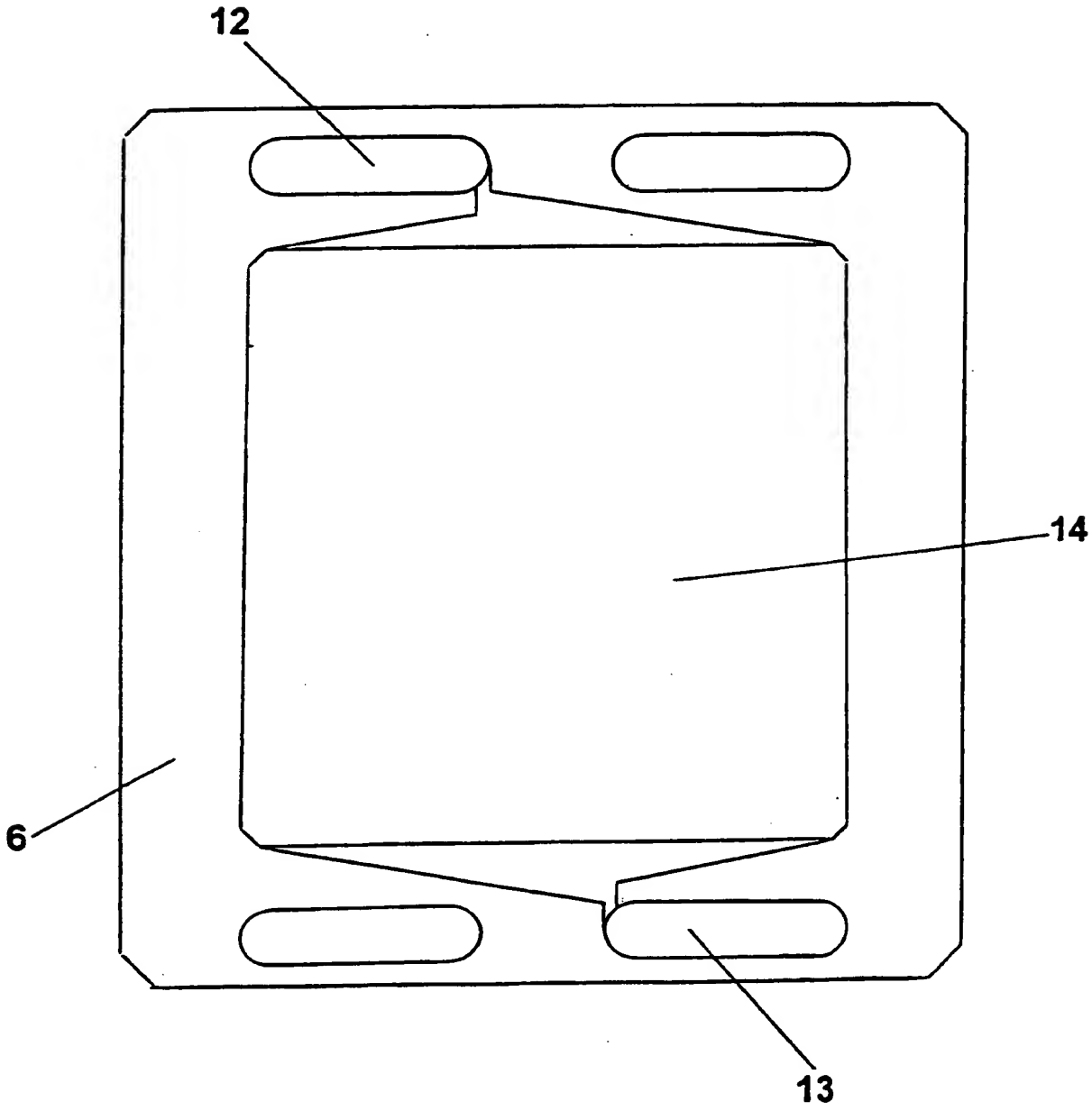


FIG. 3

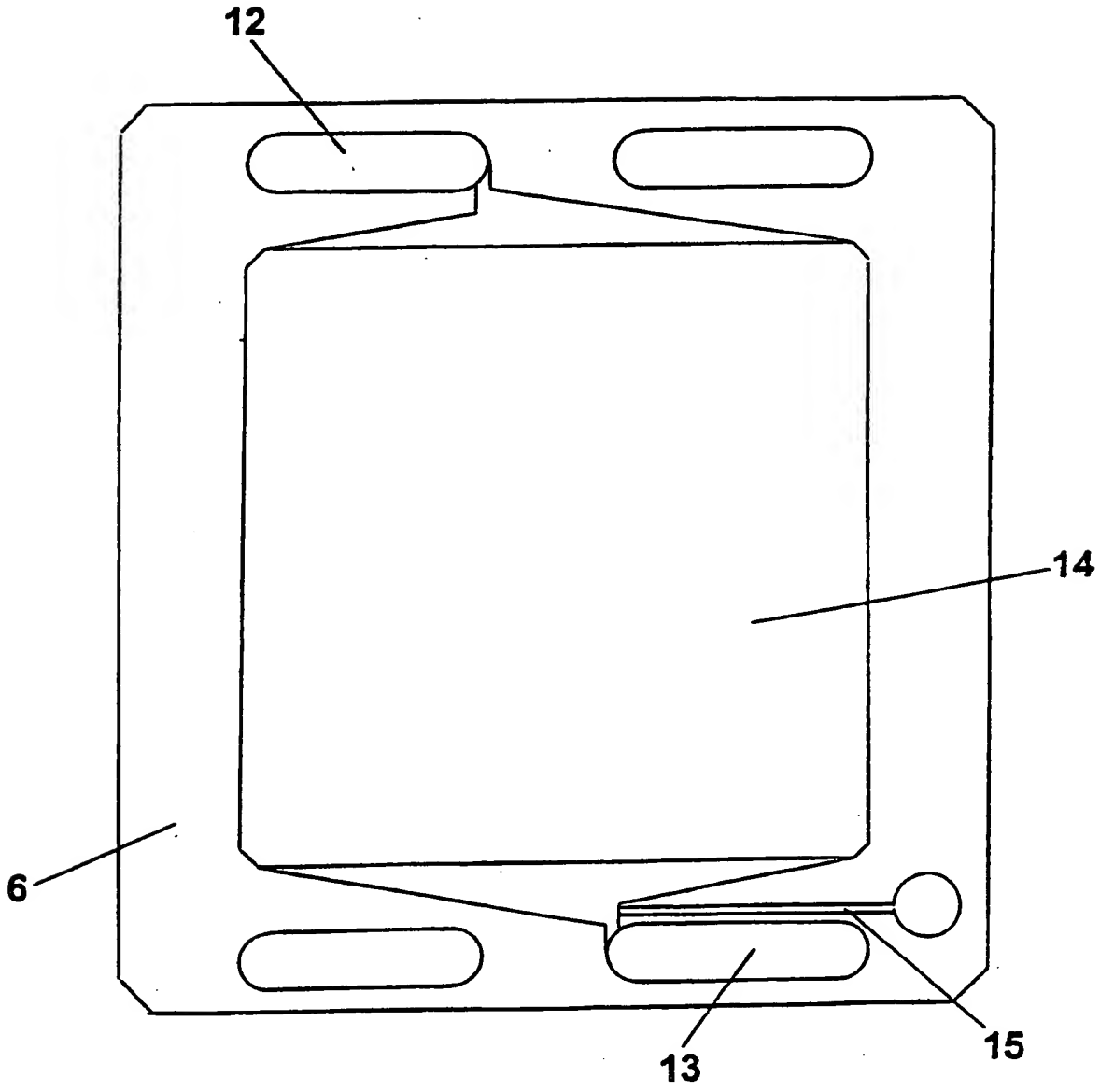


FIG. 4

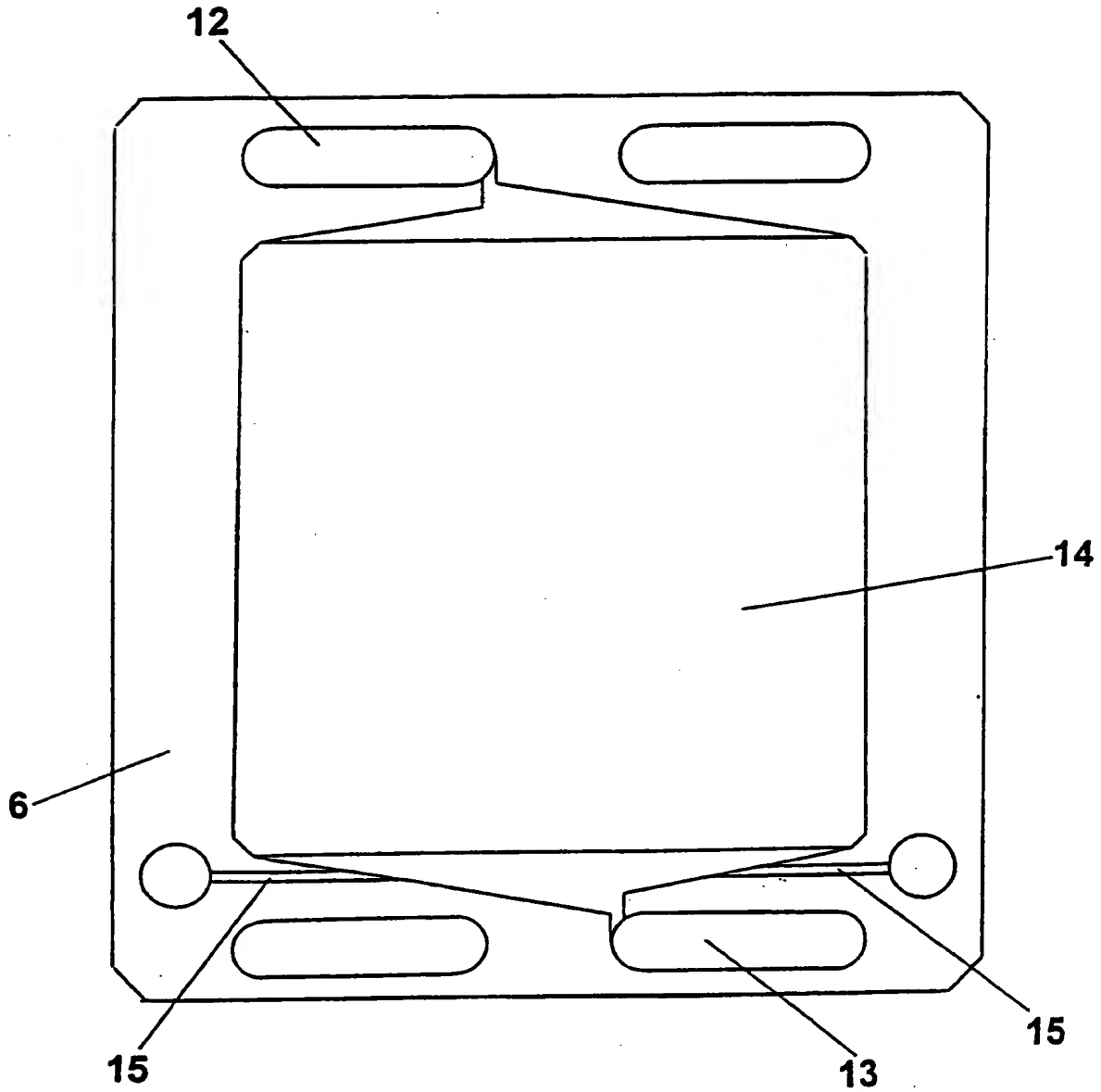


FIG. 5

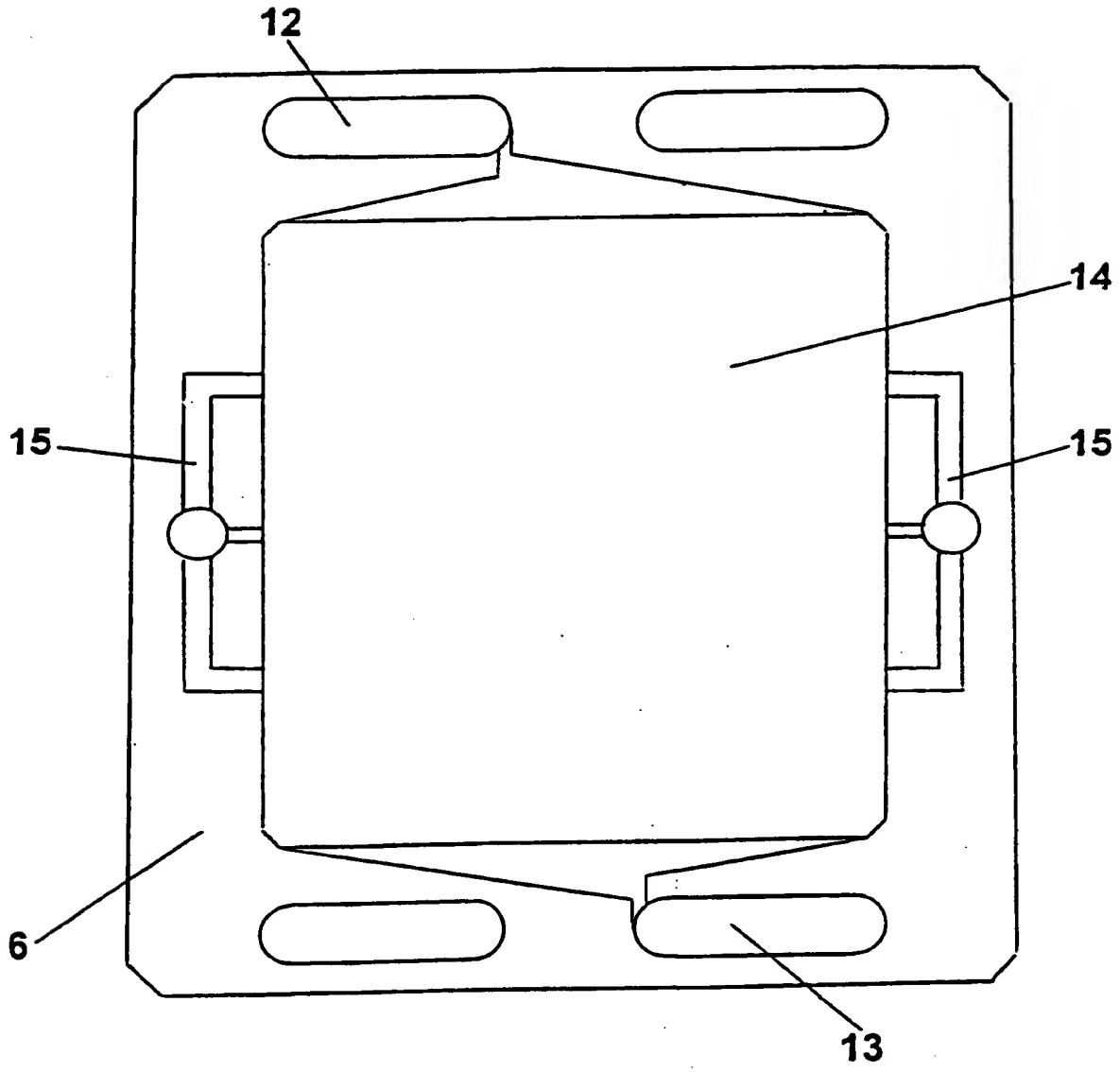


FIG. 6

FIG. 7A

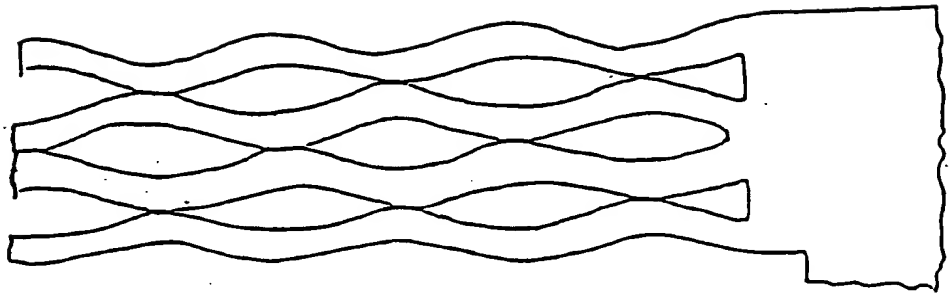
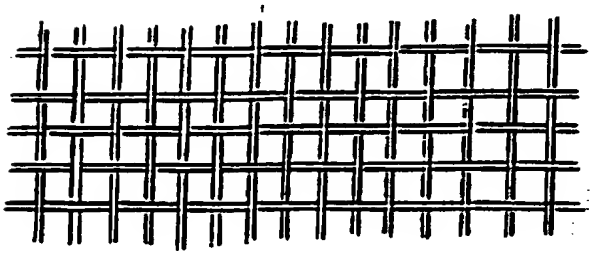


FIGURA 7B



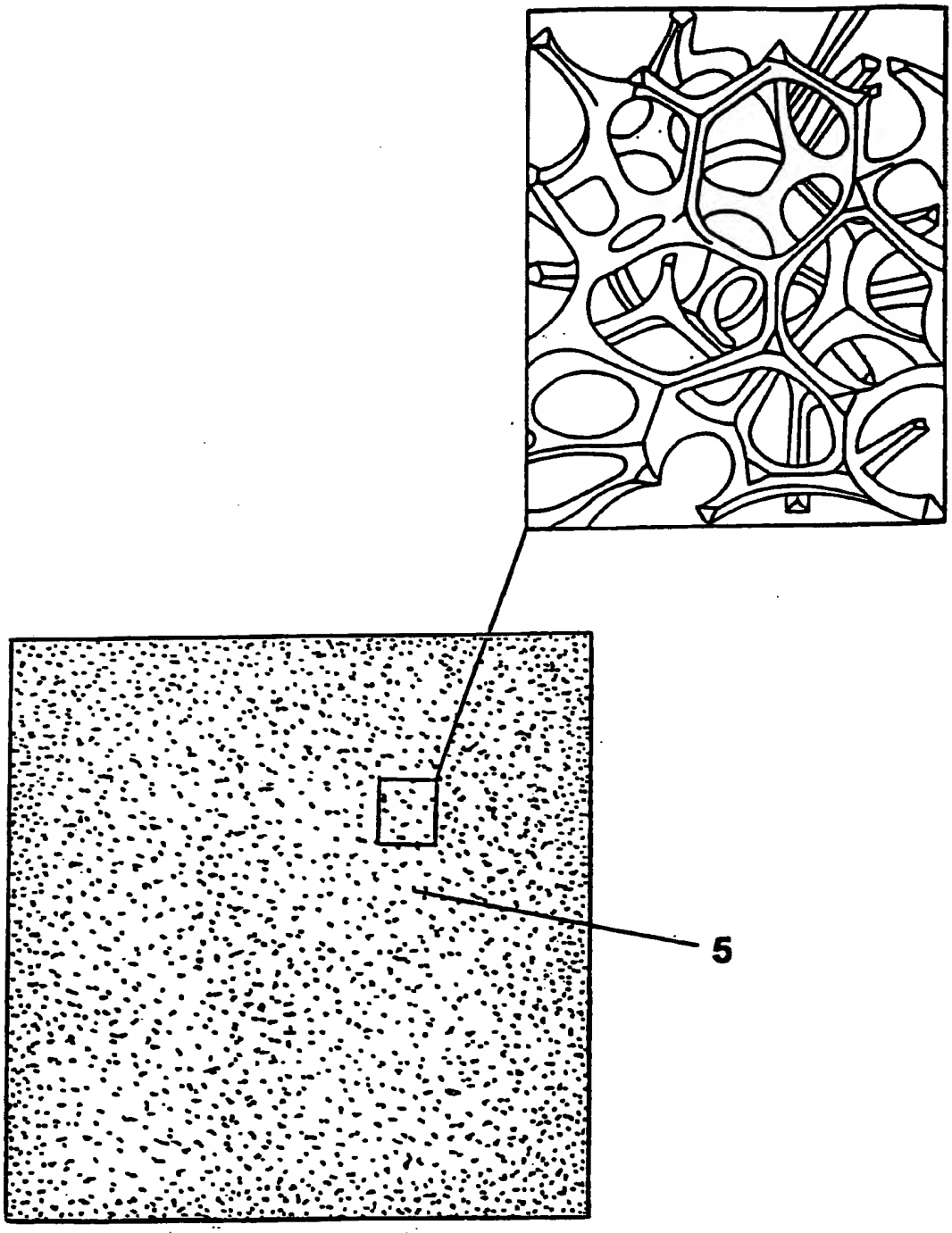


FIG. 8

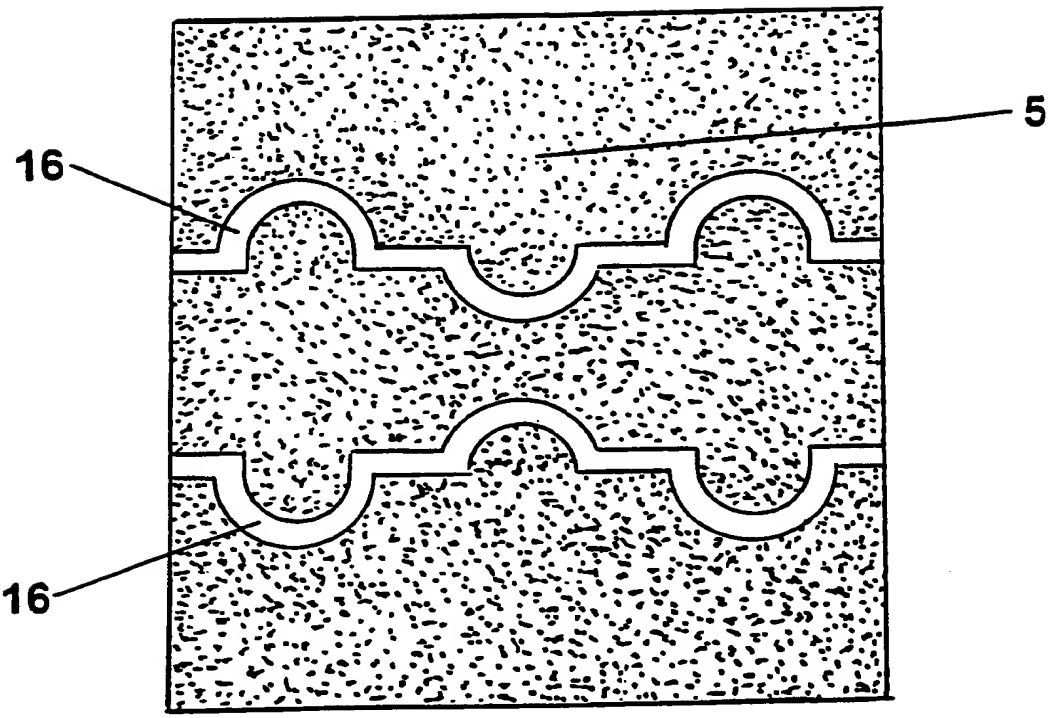


FIG. 9

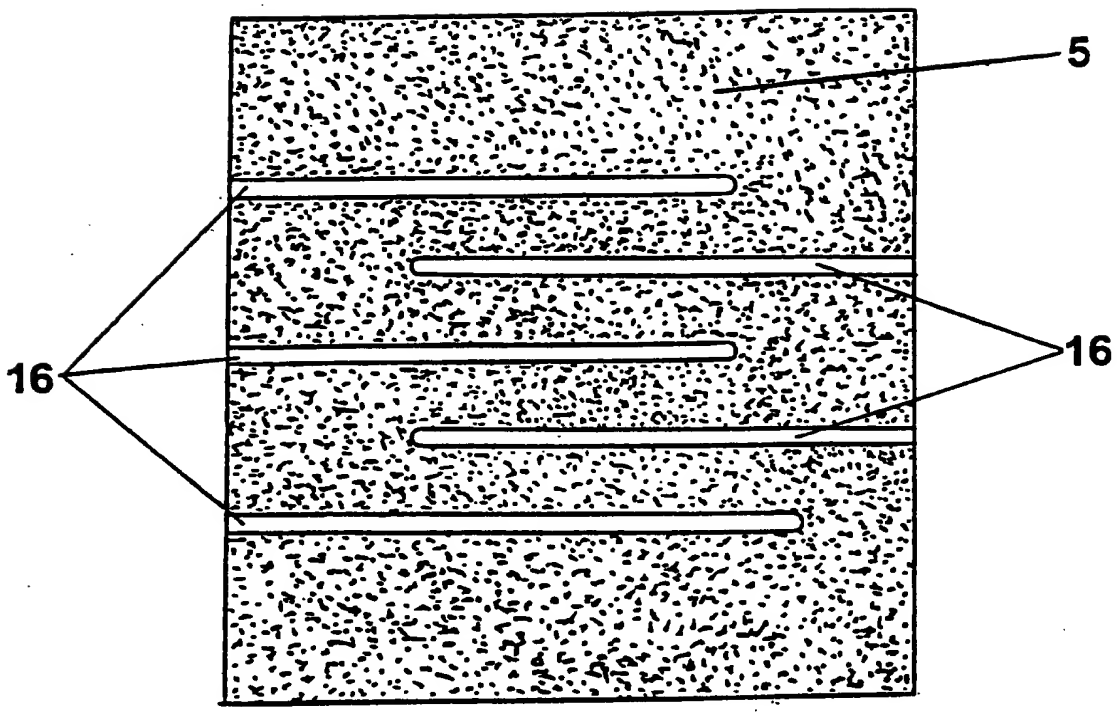


FIG. 10

INTERNATIONAL SEARCH REPORT

Int ional Application No
PCT/EP 00/03171

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01M8/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H01M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 98 45889 A (MAGNET MOTOR GMBH ;KOSCHANY ARTHUR (DE); LUCAS CHRISTIAN (DE); SCH) 15 October 1998 (1998-10-15) claims 1-3,12-14; figure 1 page 7, line 4 - line 31 page 9, line 30 - line 31	1,7,8
Y		1,2,10, 13-15

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 August 2000	06/09/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	D'hondt, J

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
X	NGUYEN T V ET AL: "A WATER AND HEAT MANAGEMENT MODEL FOR PROTON-EXCHANGE-MEMBRANE FUELS CELLS" JOURNAL OF THE ELECTROCHEMICAL SOCIETY,US,ELECTROCHEMICAL SOCIETY. MANCHESTER, NEW HAMPSHIRE, vol. 140, no. 8, 1 August 1993 (1993-08-01), pages 2178-2186, XP000403645 ISSN: 0013-4651 page 2182, right-hand column, paragraph 2; figure 3 abstract	1
Y	---	1,2,10, 13-15
Y	WO 98 33221 A (LYNNTECH INC) 30 July 1998 (1998-07-30) page 11, line 19 -page 12, line 21; figure 14A column 6, line 22 - line 24	1,2,10, 13-15
X	--- US 4 769 297 A (REISER CARL A ET AL) 6 September 1988 (1988-09-06) column 3, line 13 - line 16; claim 1; figure 1 column 4, line 67 -column 5, line 2 column 5, line 39 - line 50	1
X	--- EP 0 743 693 A (SANYO ELECTRIC CO) 20 November 1996 (1996-11-20) column 2, line 45 -column 3, line 2 column 4, line 43 - line 59; figures 3,4 column 5, line 52 -column 6, line 17 column 6, line 41 - line 54 column 11, line 11 - line 18	1
X	--- EP 0 301 757 A (UNITED TECHNOLOGIES CORP) 1 February 1989 (1989-02-01) column 3, line 56 -column 4, line 3; figure 1	1
P,X	--- US 6 015 633 A (ACKER WILLIAM P ET AL) 18 January 2000 (2000-01-18) claims 1-3,6,19; figures 2,7,8,10,15 column 5, line 57 -column 6, line 11 column 10, line 44 -column 11, line 23 column 13, line 35 - line 57 column 8, line 7 - line 11	1,7
P,X	--- WO 99 60640 A (VON HELMOLT RITTMAR ;MUND KONRAD (DE); GENENGER BERND (DE); LUFT G) 25 November 1999 (1999-11-25) page 3, line 10 - line 14; claims 1,4,5 column 4, line 1 - line 7	1
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INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 00/03171

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 328 115 A (INT FUEL CELLS CORP) 16 August 1989 (1989-08-16) claim 1; figure 1	1
A	EP 0 817 297 A (DE NORA SPA) 7 January 1998 (1998-01-07)	

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATION[redacted] SEARCH REPORT

Information on patent family members

Int[redacted]ional Application No
PCT/EP 00/03171

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9845889 A	15-10-1998	EP 0985239 A	15-03-2000
WO 9833221 A	30-07-1998	AU 6648198 A	18-08-1998
		EP 0963614 A	15-12-1999
US 4769297 A	06-09-1988	NONE	
EP 0743693 A	20-11-1996	JP 8315839 A	29-11-1996
		CA 2171380 A	19-11-1996
		DE 69602805 D	15-07-1999
		DE 69602805 T	27-04-2000
		US 5958613 A	28-09-1999
EP 0301757 A	01-02-1989	US 4795683 A	03-01-1989
		CA 1297940 A	24-03-1992
		DE 3869009 A	16-04-1992
		JP 1140562 A	01-06-1989
US 6015633 A	18-01-2000	NONE	
WO 9960640 A	25-11-1999	NONE	
EP 0328115 A	16-08-1989	US 4824741 A	25-04-1989
		CA 1309127 A	20-10-1992
		DE 68907741 D	02-09-1993
		DE 68907741 T	10-03-1994
		JP 1309263 A	13-12-1989
		JP 2057217 C	23-05-1996
		JP 7095447 B	11-10-1995
EP 0817297 A	07-01-1998	IT MI961293 A	29-12-1997
		AU 2478897 A	15-01-1998
		BR 9703725 A	27-10-1998
		CA 2207425 A	26-12-1997
		CZ 9701998 A	18-03-1998
		JP 10055805 A	24-02-1998
		NO 972774 A	19-12-1997
		SG 63718 A	30-03-1999
		SK 87097 A	14-02-2000
		US 6022634 A	08-02-2000